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JOURNAL of PALEONTOLOGY

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JOURNAL OF PALEONTOLOGY, VOL. 9, NO. 5, PP. 369–384, PLS. 37–43, JULY, 1935

ATRYPAE DESCRIBED BY CLEMENT L. WEBSTER AND RELATED FORMS (DEVONIAN, IOWA)

CARROLL LANE FENTON and MILDRED ADAMS FENTON
West Liberty, Iowa

ABSTRACT

Critical study of forms of *Atrypa* provisionally described by the late Clement L. Webster from the Devonian of Iowa reveals synonyms, unrecognizable "species," and species that are both recognizable and of value in correlating the Devonian of the Middle West and North. Several new species and subspecies are distinguished, as well as certain recognizable forms designated by letters rather than names.

In the *American Midland Naturalist* for 1921 (vol. 7, pp. 13–20), the late Clement L. Webster published a paper entitled *Notes on the genus Atrypa, with descriptions of new species*. It announced progress on a mongraph of the genus, stressed the "wonderful plasticity" of its members, and described as new, eight species and three varieties from Devonian rocks of Iowa. Seven of these were said to be illustrated on Plate 8; but through a combination of errors that plate was a reprint from a paper by C. L. Fenton. No correction was made, so that users of Webster's "*Notes*" have been confused both by erroneous figures, and by descriptions admittedly provisional.

During 1922–23, Mr. Webster cooperated with us in preparation of an account of the Hackberry faunas of Iowa (1). As a result, three of his 1921 species were redescribed and illustrated: *Atrypa devoniana*, *A owenensis* and *A. subhannibalensis*. The types themselves were unavailable, and continued so until, after their owner's death, they passed into the hands of the U. S. National Museum, where they were placed at our disposal by Dr. R. S. Bassler. Mr. F. Holly Ward allowed us to select specimens from the residue of the Webster Collection; the Carnegie Museum returned material collected by ourselves in 1924; and selected sets were lent by Dr. M. A. Stainbrook. As a result we have been able to reconsider Webster's species and to describe related species and subspecies that add significance to his distinctions.

In doing this, we have had the advantage of notes and negatives made from Webster's types when he sent them to be photographed in 1920. Thanks to the latter, we have been able to establish and limit *A. waterlooensis* and to discard supposed types of *A. gigantea* and *A. linderi*, which prove not to be the original specimens.

Publication has been delayed in the hope that further collecting would

produce specimens by means of which other problems might be solved. It has not done so, and further delay seems undesirable. Descriptions therefore are offered as they stand: clarifications of Webster's publication and supplements to it, conceived less as an isolated study than as steps toward a genetic study of the complicated genus *Atrypa*, of whose values in faunal analysis and correlation we spoke in the initial presentation of this paper (2).

Descriptions and remarks repeat all specific and subspecific names proposed by Webster, though not in the order of his paper. It has seemed wise to give separate headings even to those that are rejected, since this simplifies correlation of the two papers, from the older of which there are few quotations.

The manuscript of this paper was received by the editor of the Journal January 15, 1934.

DESCRIPTION OF SPECIES

ATRYPA WATERLOOENSIS Webster

Atrypa waterlooensis WEBSTER (part), *1921*, Am. Midland Nat., vol. 7, p. 16 (not pl. 8, figs. 1, 2).

Atrypa waterlooensis WEBSTER, vars. undescribed, FENTON and FENTON, *1932*, Am. Midland Nat., vol. 13, pl. 10, figs. 8–10.

Webster's diagnosis of this species reads as follows:

Shell orbicular in outline and sometimes a little wider than long; attains a large size; very uniform in size, structure and appearance; hinge line shorter than greatest width of the valves, closed hinge area. Dorsal valve very gibbous at or just above the centre; ventral valve flat, or strongly concave below the umbonal region, but sometimes slightly convex throughout most of its surface. Surface covered by very coarse and distant bifurcating plications and usually crossed throughout by prominent lines of growth.

The syntypes, however, include one specimen which differs markedly from the other two, exhibiting characters not stressed in Webster's generalized definition. With other specimens, it is here made the basis of a new subspecies, *websteri*, while *A. waterlooensis* is restricted to very coarsely plicate shells resembling the two remaining syntypes.

EXPLANATION OF PLATE 37

FIGS. 1—*Atrypa devoniana* Webster (Form A), brachial view of a thick specimen; Rockford, Iowa (U. S. Nat. Mus. 84666). (p. 382)

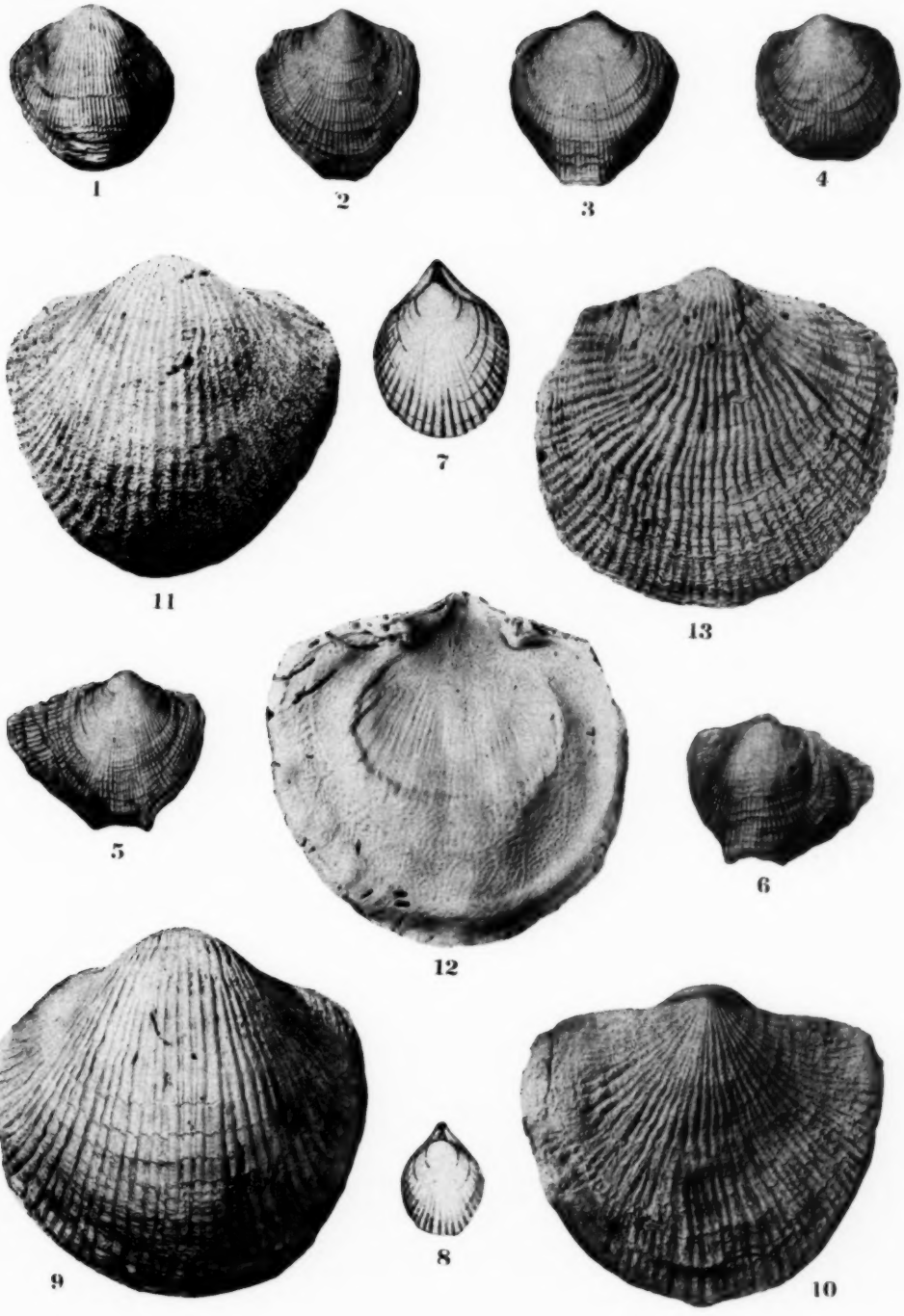
2–6—*Atrypa devoniana* Webster (Form B), Hackberry Grove, Cerro Gordo County, Iowa (U. S. Nat. Mus. 84667). 2, 3, Pedicle and brachial views of a specimen whose lamellae were not preserved. 4, Pedicle view of a typical specimen with a broad but poorly developed sinus, ×1.5. 5, 6, Pedicle and brachial views of a specimen with the lamellae preserved on one side, ×1.5. (p. 382)

7, 8—*Atrypa devoniana* Webster (Form C), brachial views of two specimens of this new form, ×2; Hackberry Grove, Cerro Gordo, County, Iowa (U. S. Nat. Mus. 84665). (p. 383)

9, 10—*Atrypa waterlooensis* Webster (Form A). 9, Brachial view of a large, exceptionally well-preserved shell in the collection of Dr. M. A. Stainbrook; *A. waterlooensis* zone, Brandon, Iowa. 10, Pedicle view of a somewhat smaller specimen, showing lamellae; Waterloo, Iowa (U. S. Nat. Mus. 84708). (p. 371)

11—*Atrypa waterlooensis* Webster (Form B), brachial view of a typical specimen; Waterloo, Iowa (U. S. Nat. Mus. 84709). (p. 371)

12, 13—*Atrypa waterlooensis* Webster (Form C), internal and external views of a pedicle valve having very broad muscular area, and showing injury to the mantle; Brandon, Iowa (U. S. Nat. Mus. 84717). (p. 371)



Fenton and Fenton, Devonian Brachiopods

Even with this restriction, it is unwise to attempt a definition which will contain qualifications adequate to designate the several variads which it must include. Instead, these variads (apparently genetic) have been separated into four forms, each for convenience designated by a letter, and each with its own diagnosis. The following generalized description deals only with characters which may be found in all.

Description.—Shells of medium or large size, originally with broad lamellar extensions which rarely are preserved; dimensions and proportions variable among forms. Pedicle valve convex umbonally, flattened or gently convex laterally; sinus, if present, wide, shallow. Brachial valve moderately to highly convex, with mesial region generally somewhat flattened or even depressed. Both valves bear strong, coarse plications that increase by bifurcation and implantation; separated by furrows relatively wide, flat, at least umbonally. Internal characters differ between forms, though apparently constant within each.

Remarks.—Since no nomenclatorial status is assigned the several "forms" of this species, the specimens illustrating them are regarded as hypotypes (3) of *Atrypa waterlooensis.*

Form A (Pl. 37, figs. 9, 10; Pl. 38, fig. 11).

Shell large, wider than long, with greatest width commonly posterior to the midlength. Hinge line nearly straight, or forming a broadly obtuse angle; extremities of adults rounded, but subangular in immature shells. Dimensions of three specimens: length of pedicle valve, 33.5, 42, 50 mm., length of brachial valve, 33.6, 43.5, 53.4 mm.; maximum width, 41.5, 51.6, 56.5 mm.; thickness, 22, 25, 29.5 mm.

Pedicle valve moderately convex umbonally, gently concave anteriorly and laterally; sinus indistinct or absent. Brachial valve regularly convex umbonally and antero-laterally, but recurved (convex) toward the extremities; fold lacking.

Plications strong and coarse; on pedicle valve, at 20 mm. from the beak, 6 to 8 in 10 mm.; at 40 mm., 5 to 6. Anteriorly the number increases somewhat by both bifurcation and implantation. Furrows from 0.5 to 1.6 mm. wide upon mesial region of brachial valve.

Occurrence.—Cedar Valley stage: Waterloo, Littleton, Brandon, and other localities in Iowa.

Hypotypes.—U. S. Nat. Mus. 84708, and one specimen in the collection of Dr. M. A. Stainbrook.

Form B (Pl. 37, fig. 11; Pl. 38, fig. 12).

Shell large, longer than wide, or with width and length about equal. Hinge line as in form A; extremities more definitely rounded. Dimensions of two specimens: length of pedicle valve, about 40.5, 46.5 mm.; length of brachial valve, 43.2, 47.3 mm.; width, 43.8, 47 mm.; thickness, 26.5, 29.5 mm.

Pedicle valve less concave than that of form A, commonly with convex extremities and shallow sinus; internally with deep, flabellate muscle scars, coarsely pitted genital area, pronounced inframarginal ridge; genital area divided by a broad, shallow channel which in some specimens bears an indistinct septum. Brachial valve highly convex, recurved near the extremities; in some specimens with shallow mesial depression.

Plications more closely spaced than in form A: at 20 mm. from the beaks, 6 to 8 in 10 mm.; at 40 mm., 6 to 8; at 60 mm., 6 to 7.

Occurrence.—Cedar Valley: Waterloo, Brandon and other localities in Iowa.

Hypotypes.—U. S. Nat. Mus. 84709.

Form C (Pl. 37, figs. 12, 13; Pl. 38, fig. 13; Pl. 39, figs. 1–4).

Shell large, longer than wide in all fully grown specimens. Hinge line forms a sharper angle than in the preceding forms; extremities rounded or (commonly) obtusely subangular. Dimensions

of three specimens, the first of which is a syntype: length of pedicle valve, 41.7, 44, 43± mm.; length of brachial valve, 41.7, 44.6, 45.3 mm.; width, 44.2, 42.8, 43 mm.; thickness, 23.5, 27, 27.5 mm.

Pedicle valve moderately convex umbonally, though with prominent beak; anteriorly and antero-laterally flattened, gently convex or very slightly concave; toward the extremities generally convex; sinus, when present, shallow, flattened. Brachial valve highly convex; slightly flattened or depressed mesially, concave near the extremities.

Plications 5 to 7 in 10 mm. at 20 mm. from the beaks, approximately the same at 40 mm. Flattened furrows 1 to 2 mm. in width common. Marginally plications increase in number by both implantation and bifurcation.

Remarks.—This form includes two of Webster's syntypes, and is perhaps the most distinctive member of the species.

Occurrence.—Cedar Valley: Waterloo, Brandon, Littleton and other localities in Iowa.

Types.—Syntypes, U. S. Nat. Mus. 78588; hypotypes, same, 84650, 84654, 84717, 84718.

Form D (Pl. 38, fig. 14; Pl. 39, figs. 5, 6).

Shell smaller than in preceding forms; extremities more pronouncedly rounded; greatest width, therefore, nearer to the midlength. Dimensions of two specimens: length of pedicle valve, 36.5, 38.2 mm.; length of brachial valve, 39.3, 40.7 mm.; width, 39, 38.7 mm.; thickness, 37, 38.2 mm.

Pedicle valve elevated, flattened umbonally, convex postero-laterally, flattened anteriorly; sinus shallow or absent. Brachial valve highly convex, flattened mesially, only slightly convex near the extremities.

Plications nearly as coarse as those of form C; at 20 mm. from the pedicle beak, typically 5 in 10 mm. Growth lamellae numerous; some specimens preserve portions of the lamellar extensions.

Occurrence.—Cedar Valley: Waterloo, Littleton, and other localities in Iowa.

Hypotypes.—U. S. Nat. Mus. 84651.

ATRYPA WATERLOOENSIS Webster, variant

Plate 41, figures 4–6

Collections from Littleton and Brandon contain specimens of a small *Atrypa*

EXPLANATION OF PLATE 38

FIGS. 1–3—*Atrypa lineata* Webster. 1, Brachial view of a typical specimen; (?) near Charles City Iowa (U. S. Nat. Mus. 84652). 2, 3, Pedicle and brachial views of a large, wide specimen; near Charles City, Iowa (U. S. Nat. Mus. 84649). (p. 379)

4–6—*Atrypa devoniana decrescens* Fenton and Fenton, n. subsp. 4, 5, Pedicle views of a paratype and the holotype, ×1.5; Hackberry Grove, Iowa (U. S. Nat. Mus. 84663, 84664). 6, Pedicle view of a specimen intermediate between *A. devoniana*, form *A* and *A. devoniana decrescens;* Rockford, Iowa (U. S. Nat. Mus. 84648). (p. 383)

7—*Atrypa lineata* Webster, anterior view of the specimen shown on Pl. 43, figs. 8, 9; near Charles City, Iowa (U. S. Nat. Mus. 84689). (p. 379)

8—*Atrypa lineata* Webster, variant, anterior view of the specimen shown on Pl. 43, figs. 10, 11; Andalusia, Illinois (U. S. Nat. Mus. 9214). (p. 380)

9—*Atrypa waterlooensis websteri* Fenton and Fenton, n. subsp., posterior view of a paratype (Pl. 39, fig. 11), one of the syntypes of *A. waterlooensis;* Waterloo, Iowa (U. S. Nat. Mus. 84644). (p. 373)

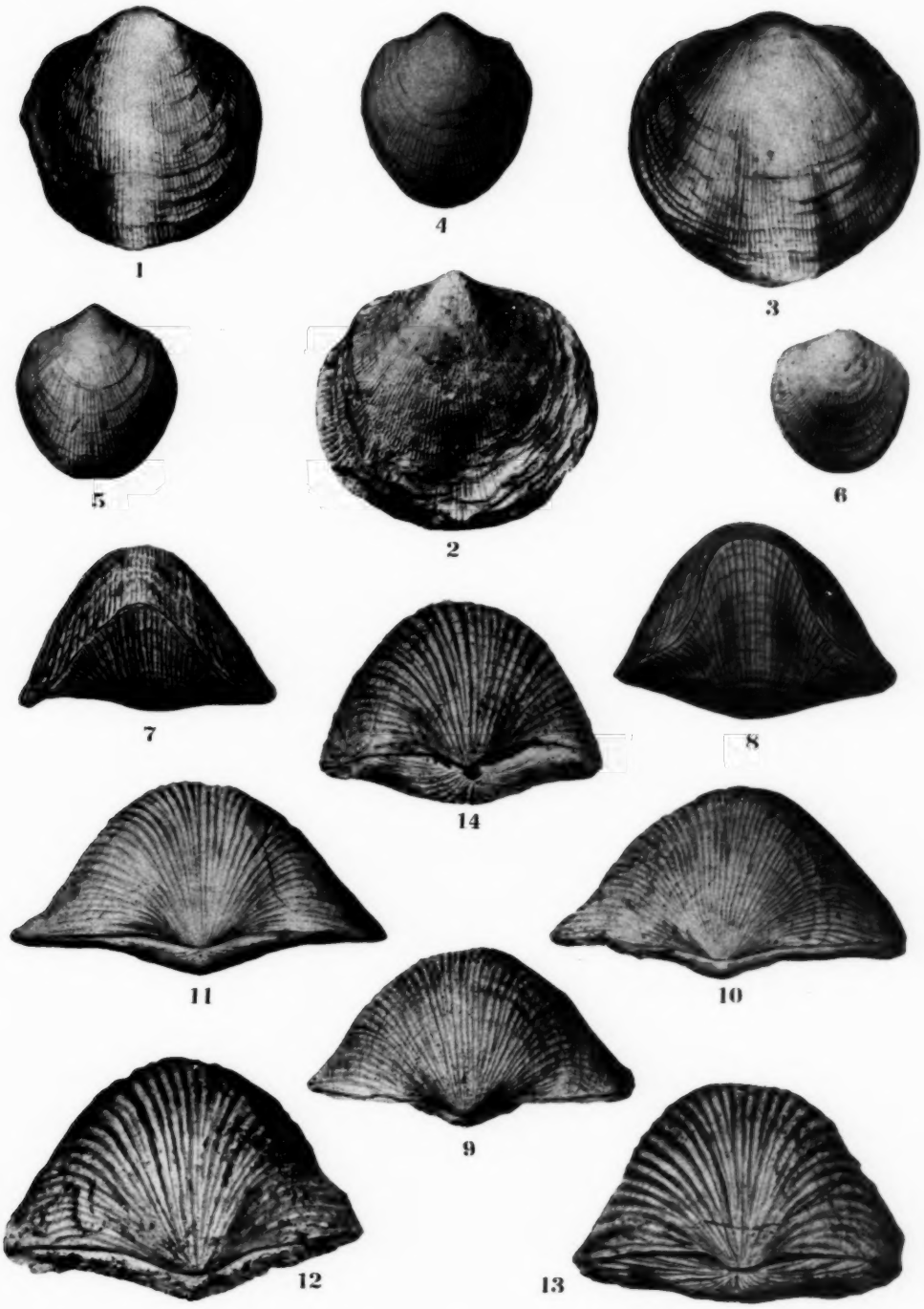
10—*Atrypa iowensis* Fenton and Fenton, n. sp., posterior view of the holotype, shown on Pl. 40, figs. 12, 13; 3.5 miles south of Cedar Falls, Iowa (U. S. Nat. Mus. 84646). (p. 374)

11—*Atrypa waterlooensis* Webster (Form A), posterior view of a specimen from Waterloo, Iowa (U. S. Nat. Mus. 84708). (p. 371)

12—*Atrypa waterlooensis* Webster (Form B), posterior view of a typical specimen; Waterloo, Iowa (U. S. Nat. Mus. 84709). (p. 371)

13—*Atrypa waterlooensis* Webster (Form C), posterior view of the specimen shown on Pl. 39, figs. 3, 4; Littleton, Iowa (U. S. Nat. Mus. 84650). (p. 371)

14—*Atrypa waterlooensis* Webster (Form D), posterior view of the specimen shown on Pl. 39, fig. 6; near Waterloo, Iowa (U. S. Nat. Mus. 84651). (p. 372)



Fenton and Fenton, Devonian Brachiopods

of the *waterlooensis* type characterized by relatively deep sinus, high fold, and numerous growth lamellae. Fold flattened; pedicle valve markedly concave postero-laterally; plications very coarse for such small shells. Specimens are too few, however, to justify description at present as a distinct subspecies, though this probably will be required.

Figured specimens.—U. S. Nat. Mus. 84706.

ATRYPA sp. cf. A. WATERLOOENSIS Webster

Plate 41, figures 1–3

Atrypa waterlooensis, so far as can be told from collections now at hand, has comparatively few close American relatives. It is interesting, therefore, to find specimens from Middle Devonian strata of Europe which resemble it closely.

Three specimens from Paffrath, Rhenish Prussia, show the coarse plications, separated by wide, flat furrows, which characterize *A. waterlooensis*. Two of them bear broad, shallow sinuses matched by indistinctly bounded folds; the third has a flattened pedicle valve without distinguishable sinus, and with the fold flattened. Plications 5 to 8 in 10 mm. at 20 mm. from the pedicle beak, and 6 to 9 at 30 mm.

The shell from the Eifelian of east Ferghana, Turkestan, figured by Nalivkin as *Atrypa reticularis* (Linné) (4), resembles the smallest of the three shells from Paffrath, but is more closely allied to variants of *A. waterlooensis* and to the coarsely plicate, early stages of *A. pronis* Fenton and Fenton, n. sp. It joins the Paffrath specimens in linking *A. waterlooensis* and its derivatives with European forms of Middle Devonian age.

Figured specimen.—U. S. Nat. Mus. 84724.

ATRYPA WATERLOOENSIS CANADENSIS Webster

Plate 40, figures 1–3

Atrypa waterlooensis var. *canadensis* WEBSTER (part), *1921*, Am. Midland Nat., vol. 7, p. 17, (not pl. 8, fig. 3).—FENTON and FENTON, *1932*, Am. Midland Nat., vol. 13, pl. 22, fig. 10.

Shell large, yet smaller than any Iowa members of the species; wider than long or with width and length about equal. Hinge line nearly straight; extremities subangular. Dimensions of two specimens: length of pedicle valve, 34.5, 34.4 mm.; length of brachial valve, 34.7, 37 mm.; width, 33.7, 38.5 mm.; thickness, 22.4, 21.5 mm.

Pedicle valve convex umbonally with sharply projecting beak; flattened to gently concave laterally and postero-laterally; sinus narrow, shallow, rounded. Brachial valve rather uniformly convex, slightly recurved near the extremities, with an indistinct fold; depressed mesial area, typical of Iowa members of *A. waterlooensis*, lacking in the two specimens at hand.

Plications strong, rounded, separated by rather shallow, rounded furrows; at 8 mm. from pedicle beak, 12 in 10 mm.; at 10 mm., 16; at 20 mm., 8 to 9. Growth lamellae numerous.

Remarks.—Webster's description states that *canadensis* differs "from the typical form of *A. waterlooensis* mainly in its generally smaller size and less coarse bifurcating plications. . . ." Although recognizing the difficulty of basing a subspecies upon two specimens, we have been unable to find a recognized form to which these may be assigned. Other specimens from the locality and formation of the syntypes show similar characters.

Occurrence.—Upper Devonian, some two miles below the first island downstream from Alexandria Falls, Hay River, Canada.

Syntypes.—U. S. Nat. Mus. 78587.

ATRYPA WATERLOOENSIS WEBSTERI Fenton and Fenton, n. subsp.

Plate 38, figure 9; Plate 39, figures 7–11

Atrypa waterlooensis var. undescribed, FENTON and FENTON, *1932*, Am. Midland Nat., vol. 13, pl. 10, figs. 3, 4, 6, 8–10.

Shell medium to large, wider than long, with the greatest width posterior to the midlength. Hinge line straight or

nearly so; cardinal extremities rounded. Dimensions of holotype and paratype: length of pedicle valve, 34.6, 45 mm.; length of brachial valve, 36.7, 49.4 mm.; width, 42, 52.5 mm.; thickness, 21.3, 37+ mm.

Pedicle valve convex in early stages; at about 15 mm. from the beak a concavity appears, U-shaped, extending posteriorly to within 8 to 10 mm. of the cardinal area; beak extending over that of the brachial valve. Brachial valve highly convex; slightly developed concavities on either side of the umbo in the postero-lateral area; slight flattening along the median line anterior to the midlength of the shell.

Surface marked by rather coarse plications that increase in number mainly by bifurcation, but also by implantation; 8 to 10 plications in 10 mm. at a distance of 20 mm. from the beak of the brachial valve; at 40 mm., of 7 to 9; similar variation on the pedicle valve. Growth lines numerous; on pedicle valve tend to give the plications a nodose appearance.

Remarks.—The paratype of this subspecies is one of Webster's syntypes of *Atrypa waterlooensis*. It seems impossible, however, to reconcile the uniformly finer plications, the more concave pedicle valve and the definitely subcordate ephebic outline with the characters shown by the other two syntypes, and stressed by Webster in his definition of the species *waterlooensis*.

Occurrence.—Cedar Valley: Waterloo, Brandon and other localities in Iowa.

Types.—Holotype, U. S. Nat. Mus. 84645; paratype, same, 84644, 84714. Other paratypes, Carnegie Mus. 4769–4774.

ATRYPA IOWENSIS Fenton and Fenton, n. sp.

Plate 38, figure 10; Plate 40, figures 12, 13

Atrypa sp. undescribed, FENTON and FENTON, *1932*, Am. Midland Nat., vol. 13, pl. 10, figs. 1, 5.

Shell large, wider than long; hinge line straight; cardinal areas rounded. Dimensions of holotype and paratype: length of pedicle valve, 40, 42.3 mm.; length of brachial valve, 42.4, 47 mm.; width, 45.6, 54 mm.; thickness, 23.3, 24 mm.

Early stages of pedicle valve appear to be quite convex; in mature individuals convexity is accentuated in the area of the muscle scars; anterior to these is a concavity apparently characteristic of this form, vanishing postero-laterally, where the valve is decidedly flattened; beak incurved well beyond that of brachial valve. Brachial valve highly convex, with maximum convexity near midlength; slight concavity in the postero-lateral area, even in young stages.

Surface marked by fine, high, subangular plications separated by furrows about one-half their width; anteriorly, few bifurcations and implantations of plications; growth wrinkles present, re-

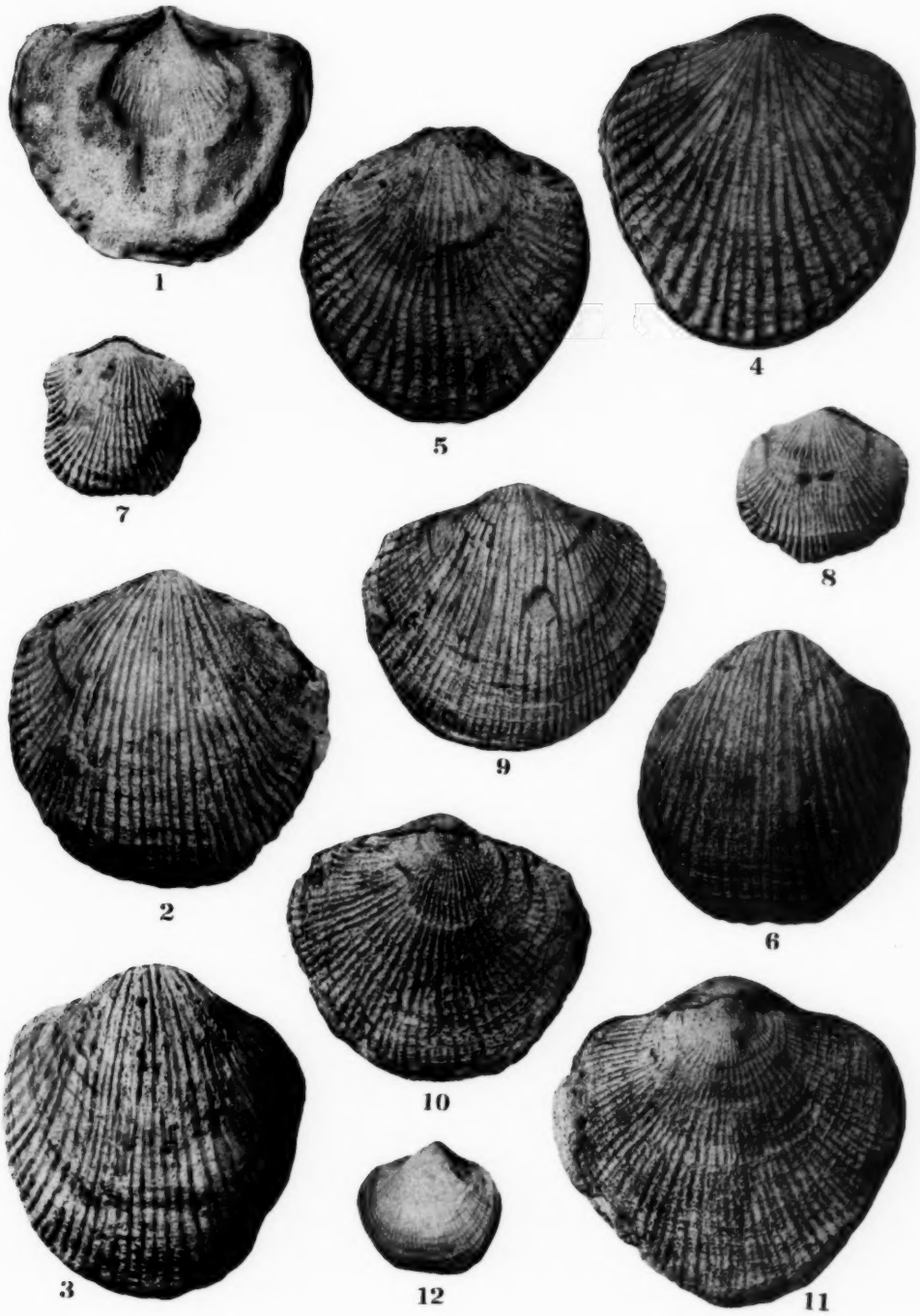
EXPLANATION OF PLATE 39

FIGS. 1–4—*Atrypa waterlooensis* Webster (Form C). 1, Interior of a pedicle valve having a very deep muscle area; 3 miles north of Waterloo, Iowa (U. S. Nat. Mus. 84718). 2, Brachial view of the principal syntype of the species; Waterloo, Iowa (U. S. Nat. Mus. 78588). 3, 4, Brachial and pedicle views of an elongate, thick specimen; Littleton, Iowa (U. S. Nat. Mus. 84650). (p. 371)

5, 6—*Atrypa waterlooensis* Webster (Form D). 5, Pedicle view of a typical specimen, with a very shallow sinus; 6, brachial view of a shorter specimen showing the mesial depression; near Waterloo, Iowa (U. S. Nat. Mus. 84651). (p. 372)

7–11—*Atrypa waterlooensis websteri* Fenton and Fenton, n. subsp. 7, 8, Brachial views of two immature specimens showing typical injury; Waterloo, Iowa (Carnegie Mus. 4771, 4773). 9, 10, Brachial and pedicle views of the holotype. 11, Pedicle view of a paratype, shown also on Pl. 38, fig. 9; Waterloo, Iowa (U. S. Nat. Mus. 84644, 84645). (p. 373)

12—*Atrypa devoniana* Webster (Form B), pedicle view of a small specimen with a broad but poorly developed sinus, ×1.5; Hackberry Grove, Iowa. (U. S. Nat. Mus. 84667). (p. 382)



Fenton and Fenton, Devonian Brachiopods

placed near the margins of mature individuals by crowded growth lines or lamellar bases. Plications in 10 mm. at 20, 40, and 60 mm. from beak of brachial valve of holotype: 14±, 10, 10 to 11; on the paratype, 11, 8, 10. Plications in 10 mm. at 20 mm. from the beak of pedicle valve of holotype, 11 to 12; on paratype, 12.

Remarks.—The pedicle valve of *A. iowensis* closely resembles that of *A. waterlooensis websteri*, and from its characters alone the two forms probably could not be distinguished. The finer, more uniform plications of the brachial valve, however, serve to delimit *A. iowensis*. Apparently the species resembles certain species of *Spirifer* in that one valve becomes differentiated in advance of the other. In both cases the valve thus accelerated in evolution is the one which grows the more rapidly, and thus may earlier abandon stages of ontogenetic survival.

Occurrence.—Cedar Valley: 3.5 miles south of Cedar Falls, Iowa.

Types.—Holotype, U. S. Nat. Mus. 84646; paratypes, same, 84642, 84690, 84692, 84695; Carnegie Mus. 4775.

ATRYPA PRONIS Fenton and Fenton, n. sp.

Plate 40, figures 4–8

Atrypa sp., FENTON and FENTON, *1932*, Am. Midland Nat., vol. 13, pl. 22, figs. 7, 8.

Shell smaller than in any forms of *Atrypa waterlooensis* Webster; length greater than width, or with the two dimensions about equal. Hinge line obtusely angular in the more gibbous shells, but nearly straight in those which resemble the holotype. Dimensions of three specimens, the second of which is the holotype: length of pedicle valve, 18.8, 26.7, 34 mm.; length of brachial valve, 18.7, 27.5, 35.5 mm.; width,—, 27, 33 mm.; thickness, 12.4, 20.7, 27 mm.

Pedicle valve convex umbonally and anteriorly for a distance of 14 to 18 mm.; beak produced but obtuse; sinus broad, shallow, rounded; lingual extension commonly abruptly recurved; postero-lateral regions concave or flattened. Brachial valve highly convex umbonally, flattened, though steep, on the lateral slopes; fold indistinctly bounded, rounded to subangular, with (rarely) a mesial depression.

Plications strong, angular, between deep, rounded furrows; on pedicle valve 9 to 11 at 10 mm. from the beak; at 20 mm., 7 or 8; beyond 20 mm. increased somewhat by bifurcation and implantation. Growth lamellae numerous, closely spaced in ephebic stages.

Remarks.—The specimens on which this description is based were collected, perhaps half a century ago, by Orestes H. St. John, then of Waterloo, Iowa. They contain two forms, one of which (represented by the holotype) has the extremities more compressed than does the other, with hinge-line more nearly straight. Specimens at hand, however, are too poorly preserved to justify separation.

Occurrence.—Cedar Valley: Waterloo, Iowa.

Types.—Holotype, U. S. Nat. Mus. 84674; paratypes, same, 84679.

ATRYPA PRONIS ONUSTA Fenton and Fenton, n. subsp.

Plate 40, figures 9–11

Shell larger than in the preceding, with hinge line more uniformly obtuse, extremities markedly rounded. Dimensions of three specimens: length of pedicle valve, 34±, 34±, 32± mm.; length of brachial valve, 34.6, 34, 35.5 mm.; width, 34.5, 36.7, 38.2 mm.; thickness, 26.5, 26, — mm.

Pedicle valve less convex umbonally than in *A. pronis*, with beak, however, markedly produced; postero-lateral regions flattened to concave; sinus very shallow, concave or flattened. Brachial valve strongly convex, with abruptly sloping marginal regions; fold indistinguishable, or replaced by a shallow sinus.

Plications strong, subangular, between deep furrows; on pedicle valve, at 10

mm. from the beak, 9 to 11 in 10 mm.; at 20 mm., 8 to 10; on brachial valve, at 20 mm., 6 to 8; at 20 mm. from the beak most plications bifurcate, furrows become shallow and wider; marginally the number of plications typically 8 in 10 mm. Some specimens preserve lamellar extensions, but lamellae less closely spaced than in *A. pronis*.

Remarks.—In shape this subspecies appears to connect *A. pronis* with *A. waterlooensis*, form A or B, the dominant relationship being with the former.

Occurrence.—Cedar Valley: Waterloo, Iowa, collected by Orestes H. St. John.

Types.—Holotype, U. S. Nat. Mus. 84677; paratypes, same, 84678.

ATRYPA GIGANTEA Webster

Atrypa gigantea WEBSTER, *1921*, Am. Midland Nat., vol. 7, p. 16.

The supposed types of this species are too poorly preserved to warrant description. The true types seem to have been lost. With abundant good specimens at hand, it is improbable that Webster would have chosen these fragments, which do not bear his original label, and which fail to show the internal characters which he notes. Unfortunately, no specimens of *A. gigantea* were photographed for the original publication, nor are manuscript notes on the species to be found.

The fragments numbered 78607, U. S. Nat. Museum, seem to be identical with *A. waterlooensis*, as here defined from known syntypes. Were their identity as types certain, or even probable, *A. gigantea* would replace that species, whose description it immediately precedes. As things stand, however, it seems necessary to reject *A. gigantea* as undeterminable and retain *A. waterlooensis*.

Specimens, probably not types.—U. S. Nat. Mus. 78606, 78607, 84725.

ATRYPA TROWBRIDGEI Fenton and Fenton

Plate 41, figures 7, 8; Plate 42, figures 7, 8

Atrypa trowbridgei FENTON and FENTON, *1930*, Am. Midland Nat., vol. 12, p. 14, pl. 2, figs. 1, 2; *1932*, Am. Midland Nat., vol. 13, p. 207, fig. 2B, pl. 22, fig. 9.

The holotype and paratypes of this species were collected from a fine-grained, relatively pure limestone. A number of specimens in the Webster collection, from a stratum of calcareous shale, add to the range of characters shown by the species.

They show three extremes in its development: compact shells which closely resemble the holotype (Pl. 42, figs. 7, 8); highly convex shells with broadly alate lamellae, deeply indented at the sinus (Pl. 41, fig. 7); and relatively wide specimens whose lamellae were thick, but apparently not greatly expanded (Pl. 41, fig. 8). The second and third of these were not distinguishably represented in the original material.

Shells of the shale facies agree with those from the limestone in having coarse, rounded plications umbonally, separated by broad, concave furrows. At 12 to 14 mm. from the beaks most

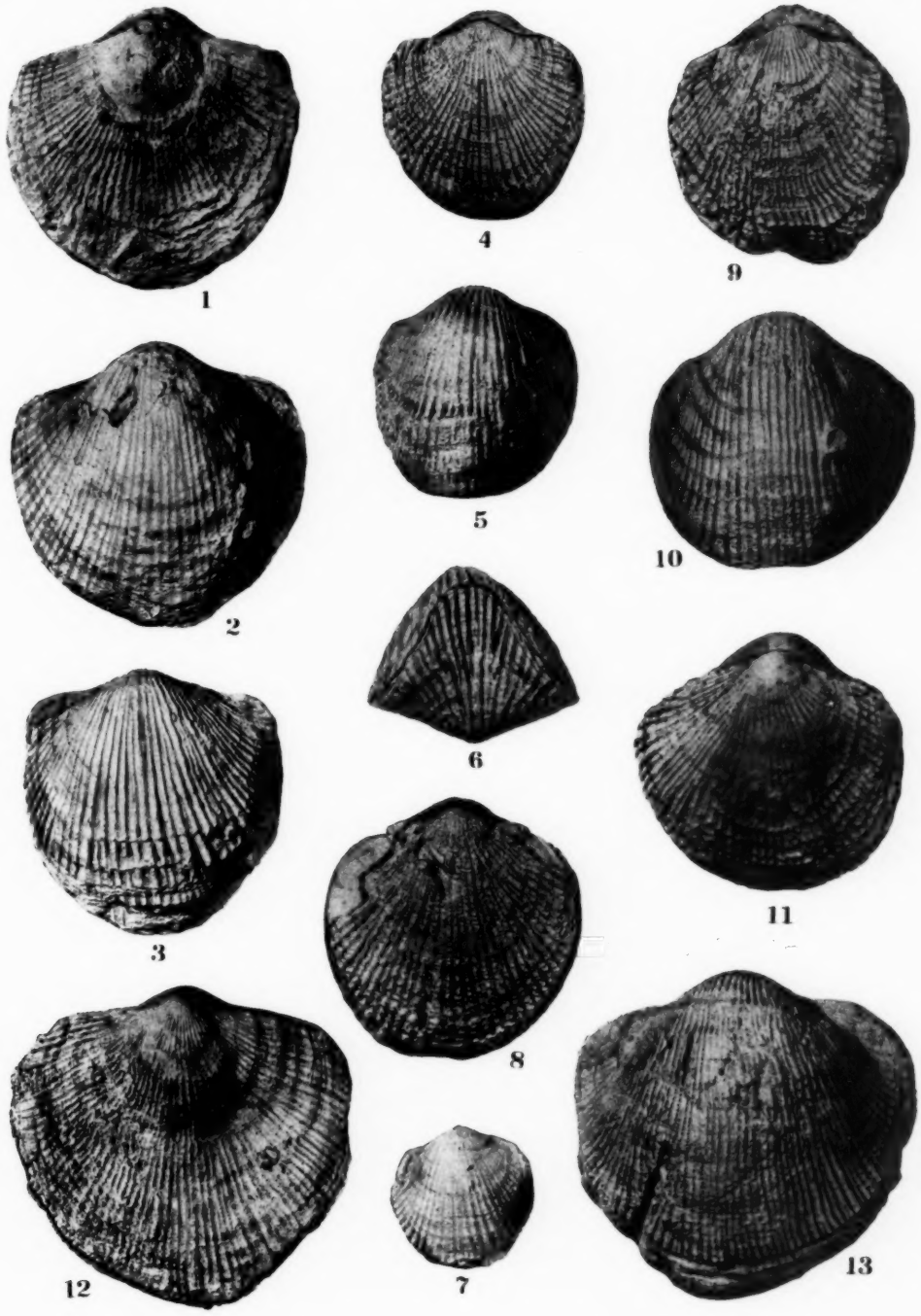
EXPLANATION OF PLATE 40

FIGS. 1–3—*Atrypa waterlooensis canadensis* Webster. 1, 2, Pedicle and brachial views of the larger of the two syntypes; 3, brachial view of the smaller syntype; near Alexandria Falls, Hay River, Canada (U. S. Nat. Mus. 78587). (p. 373)

4–8—*Atrypa pronis* Fenton and Fenton, n. sp., Waterloo, Iowa. 4–6, Pedicle, brachial, and anterior views of the holotype (U. S. Nat. Mus. 84674). 7, Brachial view of a young specimen, a paratype. 8, Pedicle view of a large, senile paratype (U. S. Nat. Mus. 84679). (p. 375)

9–11—*Atrypa pronis onusta* Fenton and Fenton, n. subsp., Waterloo, Iowa. 9, Pedicle view of the holotype (U. S. Nat. Mus. 84677). 10, 11, Brachial and pedicle views of a paratype (U. S. Nat. Mus. 84678). (p. 375)

12, 13—*Atrypa iowensis*, Fenton and Fenton, n. sp., pedicle and brachial views of the holotype, a specimen showing injury to the mantle of both valves; 3.5 miles south of Cedar Falls, Iowa (U. S. Nat. Mus. 84646). (p. 374)



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of these plications bifurcate; on the brachial valve there is further increase by implantation. In some specimens, bifurcation dominates the pedicle valve, implantation the brachial. The sinus is shallow and marginal, but in virtually all specimens from the shale bed, it is concave and abruptly upturned. Growth lamellae are thickest in wide specimens.

Occurrence.—Lower Cedar Valley: Linn Junction and other localities, Linn County, Iowa; Linder's Quarry, north of Iowa City.

Types.—Holotype, Walker Mus. Univ. Chicago 26097; paratypes, same, 26098, 26099. Hypotypes, U. S. Nat. Mus. 84671, 84673.

ATRYPA INDEPENDENCIS Webster

Plate 41, figures 9–12; Plate 42, figures 14–16; Plate 43, figure 12

Atrypa reticularis HALL (part), *1858*, Geol. Survey Iowa, Rept., vol. 1, pt. 2, p. 515, pl. 6, figs. 4, 5.—HALL, *1867*, Pal. New York, vol. 4, p. 320, pl. 53, figs. 14, 15, (16?).—HALL and CLARKE, *1894*, Pal. New York, vol. 8, pt. 2, p. 168.—THOMAS, *1916?*, Iowa Acad Sci., Proc., vol. 23, p. 173, pl. 5C.

Atrypa independensis WEBSTER (part), *1921*, Am. Midland Nat., vol. 7, p. 15 (not pl. 8, figs. 4–6).

Atrypa independencis FENTON and FENTON, *1932*, Am. Midland Nat., vol. 13, p. 206, fig. 1, pl. 21, figs. 1–4.

Atrypa expansa Webster, *1921*, Am. Midland Nat., vol. 7, p. 15.

Shells large; mature specimens subquadrate, usually wider than long even when lacking the lamellar extensions; young specimens longer than wide. Dimensions of three specimens (the second certainly one of Webster's syntypes; the third probably one): length of pedicle valve, 14.5, 37, 41 mm.; length of brachial valve, 13.6, 35, 39.3 mm.; maximum width, 13.9, 37.7, 41 mm.; thickness at the midlength, 7, 20.3, 26 mm. In the first specimen the thickness is equally divided between the two valves; in the second it represents the brachial valve only; in the third, only 3 mm. are occupied by the pedicle valve.

Pedicle valve convex umbonally; in young specimens, 10 to 25 mm. long, equal to the brachial; postero-lateral areas flattened on either side of the umbo. In neanic stages extremities rounded, in ephebic and gerontic stages angular or subangular; hinge line straight or nearly so throughout; in neanic stage

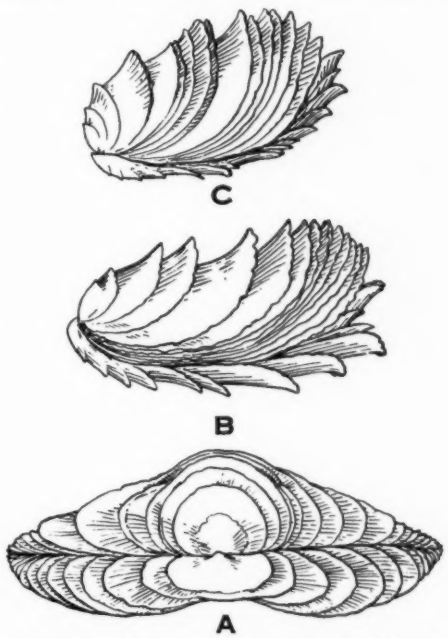


FIG. 1. Alate lamellae in *Atrypa independencis* Webster; posterior and lateral views of shells with lamellae restored. Reduced.

pedicle beak prominent, extending beyond brachial valve, with very small foramen. With growth, beak becomes incurved, finally bent closely over beak of brachial valve, with foramen closed. Cardinal area small; in ephebic and gerontic stages, like the foramen, it is more or less hidden by the very convex brachial umbo. About 20 mm. from beak the shallow, rather broad sinus arises; lamellae obscure it, giving pedicle valve in general a flat appearance. In a hypotype, a slight concavity appears between growth lamellae 17 to 24 mm. from the beak; at 24 mm. a lamella extends outward until (in one place) it is 12.5 mm. beyond the margin of the brachial valve.

Brachial valve regularly convex umbonally, recurved toward the extremities, flattened laterally; fold, a broad, rounded to subangular elevation not clearly demarked from general convexity of the shell.

Plications increase by bifurcation on the body of the pedicle valve, by bifurcation and implantation on that of the brachial. Plications of valves of figured syntype same in size at comparable distances from the beaks. Great variation in size of plications among the many specimens at hand; plications at 5, 15, and 30 mm. from the brachial beak of the figured syntype 14, 11, 9 in 5 mm., respectively; on other specimens from 14 to 18 for the first, 9 to 11 for the second, and 6 to 9 for the third. On both valves, lamellae extend outward from structures usually considered growth lines; lamellae have the same type of plication and appearance as the body of shell except that "growth lines" are lacking. On brachial valves the lamellae apparently were more conservative than on pedicle valves, and in most cases not well preserved. Variations in spacing and prominence of growth lamellae are well shown by the illustrations; on brachial valves these lamellae commonly are 5 to 7 mm. apart.

Remarks.—Webster described *Atrypa independencis* chiefly by quoting Hall's diagnosis of the specimens illustrated in 1858. In 1867 (p. 320), Hall again considered the *Atrypa* from Independence, remarking that it

> acquires a large size and presents some peculiarities, particularly in the straight extended hinge and the subcarinate dorsal valve. These features have not been observed in specimens from the Hamilton Group of New York, though simulated by some specimens of the Chemung Group. . . .

The illustrations accompanying this comment show, better than do those of the *Geology of Iowa*, the distinguishing characters of Webster's species, especially the widely spaced major lamellae. A somewhat similar specimen is illustrated by Thomas (his Pl. 5C, figs. 7, 8), although its pedicle valve is unusually deep and its beak but slightly incurved.

Thomas also illustrates (his Pl. 5C, figs. 1, 2) the large specimen which, at least by implication, seems to be the type of Webster's species *A. expansa*. From examination of a considerable number of specimens it seems clear that *A. expansa* differs from *A. independencis* only in the preservation of alate lamellae. Doubtless there are some specimens in which the lamellae are much wider in proportion to the body of the shell than in others, but differences are not uniform and seem consistent with physiologic variation. In the majority of cases, however, poor preservation or considerable weathering seems responsible for lack of alations in *A. independencis*, of which *A.*

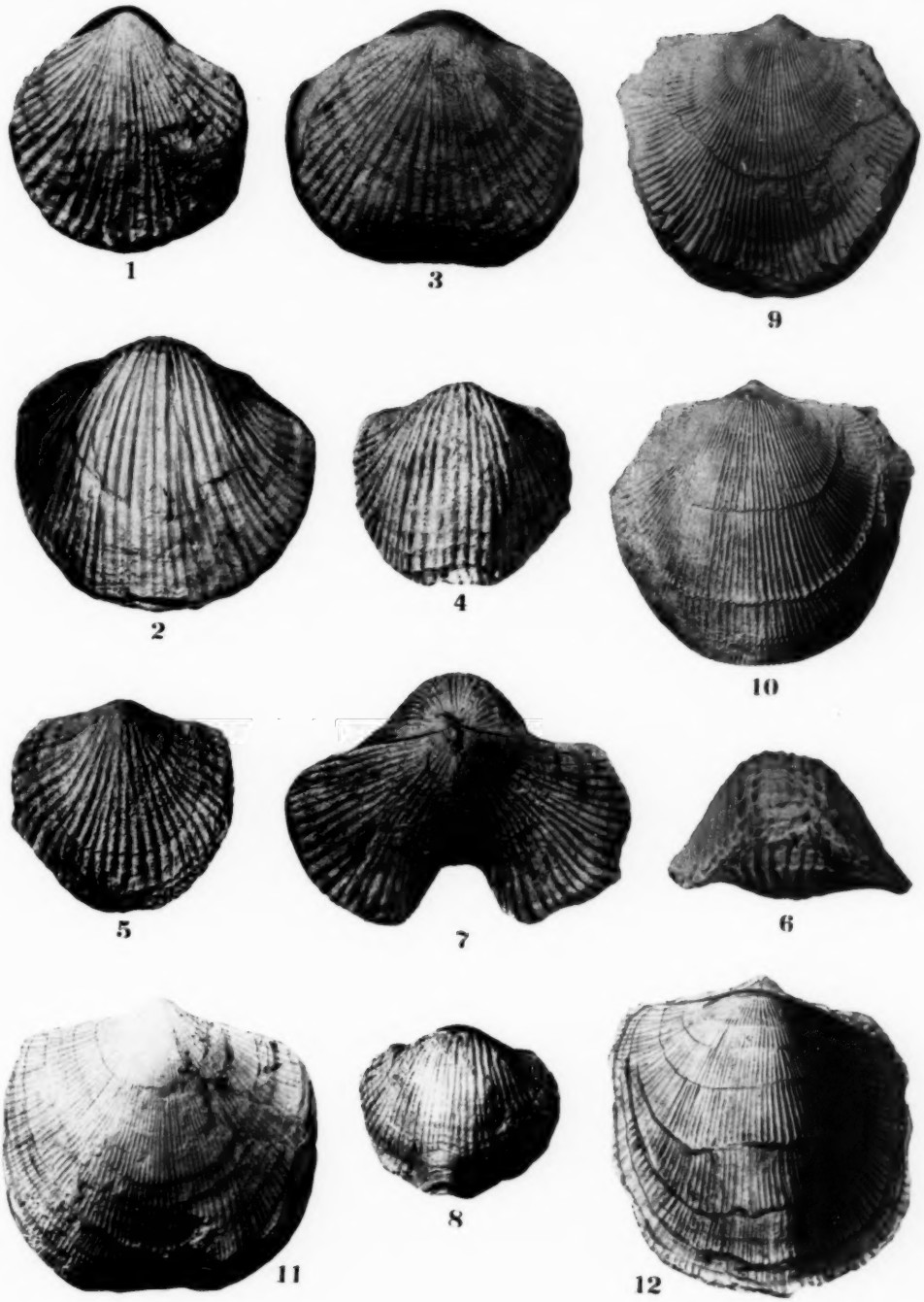
EXPLANATION OF PLATE 41

FIGS. 1–3—*Atrypa* cf. *A. waterlooensis* Webster, Paffrath, Rhenish Prussia. 1, Pedicle view of a narrow specimen. 2, 3, brachial and pedicle views of a wider specimen (U. S. Nat. Mus. 84724). (p. 373)

4–6—*Atrypa waterlooensis* Webster, variant, brachial, pedicle, and anterior views of a small, but typical specimen of this variant; Littleton, Iowa (U. S. Nat. Mus. 84706). (p. 372)

7, 8—*Atrypa trowbridgei* Fenton and Fenton. 7, Pedicle view of a senile specimen with alate lamellae; near Iowa City, Iowa (U. S. Nat. Mus. 84671). 8, Brachial view of a relatively broad specimen; Linder's Quarry, near Iowa City, Iowa (U. S. Nat. Mus. 84673). (p. 376)

9–12—*Atrypa independencis* Webster. 9, 10, Pedicle and brachial views of a specimen bearing coarse plications; the lamellae are partly preserved; Big Bend, Johnson County, Iowa (U. S. Nat. Mus. 84681). 11, Pedicle view of a more typical specimen in which only the bases of lamellae remain; Independence, Iowa (Walker Mus. 25877). 12, Brachial view of a coarsely plicate shell with an exceptionally prominent beak; Independence, Iowa (U. S. Nat. Mus. 84653). (p. 377)



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expansa therefore is considered a synonym.

Occurrence.—Lower Cedar Valley (*Spirifer "pennatus"* beds and others): near Independence, Waverly, Solon and other localities in Iowa; apparently in later beds near Iowa City. Apparently also in the Devonian of Snake Island, Lake Winnepegosis, and East and Pentamerus Points, Lake Manitoba.

Types.—Syntypes, U. S. Nat. Mus. 78608, 84688, 84727; hypotypes, same, 84640, 84653, 84681, 84687, 84720; Walker Mus., Univ. Chicago 25877, 25994.

Atrypa independencis janesvillensis Fenton and Fenton, n. subsp.

Plate 42, figures 9–13

Shells subquadrate, of slightly more than medium size, wider than long. Dimensions of holotype and two paratypes: length of pedicle valve, 23, 23.6, 34.5 mm.; length of brachial valve, 22.3, 25, —, mm.; width, 28, 32.5, 43.6; thickness, 19.5, 21,—, mm.

Pedicle valve convex umbonally, flattened laterally and anteriorly; somewhat anterior to the midlength a broad, shallow sinus arises; hinge line straight, cardinal extremities rounded; pedicle beak extends only slightly beyond umbonal region of brachial valve; foramen prominent.

Brachial valve variable in convexity; fold low, broadly arched or high and acute, depending upon general convexity.

Lamellae present on both valves though only remnants preserved; growth lines numerous near the margins. Plications increase in size from beak anteriorly; bifurcation and implantation not common; plications number 9 to 11 in 5 mm. at 5 mm. from beak of brachial valve, 8 to 9 at 25 mm. from the beak.

Remarks.—Smaller size, thinner shell, more compressed postero-lateral regions and more abruptly demarked sinus distinguish this subspecies from the typical form. Though perhaps an ecad rather than a taxonomic unit, it seems to merit special designation.

Occurrence.—Lower Cedar Valley: Janesville, Iowa.

Types.—Holotype, U. S. Nat. Mus. 84682; paratypes, same, 84683, 84684, 84685.

Atrypa expansa Webster

Atrypa expansa Webster, *1921*, Am. Midland Nat., vol. 7, no. 1, p. 15.

The "marginal fringe" or "foliated expansion" that was considered by Webster to distinguish *A. expansa* is found to be a common character of *A. independencis*, all specimens of which show evidence of this ornamentation during life. Since no other distinguishing characters can be found, *A. expansa* is considered synonymous with *A. independencis*, whose description holds precedence, and of which types are known.

Atrypa lineata Webster

Plate 38, figures 1–3, 7; Plate 43, figures 8, 9

Atrypa lineata Webster (part), *1921*, Am. Midland Nat., vol. 7, p. 17 (not pl. 8, figs. 7–8).—Fenton and Fenton, *1932*, Am. Midland Nat., vol. 13, p. 207, fig. 2B.

Shells large; orbicular to subquadrate in outline, wider than long in neanic and in some ephebic stages; in perhaps the most typical ephebic stages, however, length exceeds the width and convexity or thickness increases in proportion to decrease in width; such specimens appear to be compressed longitudinally. Dimensions of two specimens: length of pedicle valve, 38, 36.3 mm.; length of brachial valve, 37, 37.3 mm.; width, 41, 34.3 mm.; thickness, 22, 21 mm.

Pedicle valve in early stages (to about 10 mm. length) with convexity equal to that of brachial; beyond this stage the shell flattens laterally and anteriorly to about midlength, where the sinus begins; some specimens with a deflection near lateral margins, accompanied or produced by crowding of growth lines or lamellae, giving an appearance of concavity between umbo and lateral margins

of shell. Sinus, arising at about midlength of shell, broad, shallow, flat in specimens whose width exceeds length; narrow, deep, concave in specimens whose length exceeds width. Cardinal extremities rounded in ephebic stages, though angular in early neanic stages.

Brachial valve highly convex umbonally; length (in typical ephebic and gerontic shells) somewhat greater than that of pedicle; antero-medially convexity diminishes; sinus matched by poorly defined, rounded or generally subangular fold; in most specimens antero-lateral slopes are flattened, descending abruptly to margins.

Surface of both valves marked by fine plications that increase by bifurcation and implantation; plications increase in size anteriorly; 8 to 10 plications in 5 mm. at about midlength of a mature individual, 5 to 7 at anterior margin; variation in the character of the plications greater at margin than at midlength. Growth lines irregularly spaced throughout, crowded at margins of gerontic specimens; commonly they take the form of wrinkles rather than lamellae.

Remarks.—*A. lineata* can be distinguished from *A. independencis* by its fine plications, subovate outline, and convexity. Fluctuation within the species is less significant than it may seem, since fully three-fourths of the specimens belong to the typical, narrow form.

Occurrence.—Upper Cedar Valley: near Charles City and other localities, Floyd County, Iowa.

Types.—Syntypes, U. S. Nat. Mus. 78609, 84739?, 84747; hypotypes, same, 84649, 84652, 84689.

Atrypa lineata Webster, variant

Plate 38, figure 8; Plate 43, figures 10, 11

Two specimens from the Cedar Valley of Andalusia, Illinois, show characters which differentiate them from the typical *A. lineata*, although they seem to be members of that species. On the pedicle valve the sinus is broad and concave, with a flattened, abruptly curved lingual extension. On the brachial valve the fold is broad and rounded, and is bounded by abrupt, subangular depressions. Growth lamellae are reduced to lines or wrinkles.

The form resembles that from Bake-Oven, Illinois, figured by Hall (Pal. New York, vol. 4, pl. 52, figs. 4–6), but is wider, less tumid and has a narrower sinus and lingual extension. These, with *A. inflata* Webster, suggest considerable local differentiation of the *A. lineata* stock within the Iowa-Illinois basin.

Specimens.—U. S. Nat. Mus. 9214.

Explanation of Plate 42

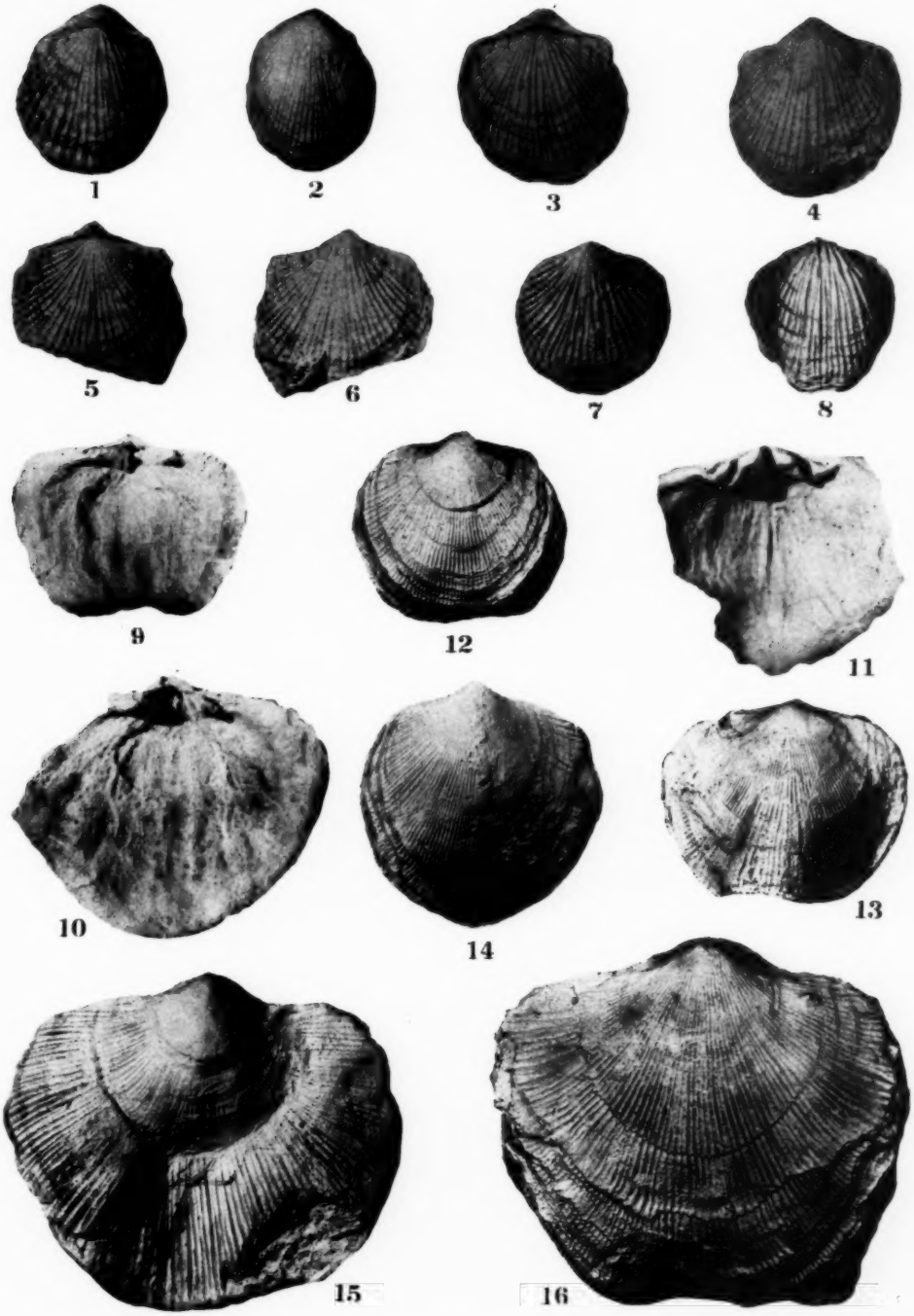
Figs. 1, 2—*Atrypa owenensis* Webster (Form A), brachial and pedicle views of large specimens of this form, ×1.5; 2 miles west of Bird Hill, Cerro Gordo County, Iowa (U. S. Nat. Mus. 84696). (p. 383)

3–6—*Atrypa owenensis* Webster (Form B). 3, 4, Brachial and pedicle views of a complete but slightly distorted specimen, ×1.5; 5, 6, brachial and pedicle views of a damaged specimen, ×1.5; 2 miles west of Bird Hill, Cerro Gordo County, Iowa (U. S. Nat. Mus. 84697). (p. 384)

7, 8—*Atrypa trowbridgei* Fenton and Fenton. 7, Pedicle view of a typical specimen; 8, brachial view of a narrow specimen; Linder's Quarry near Iowa City, Iowa (U. S. Nat. Mus. 84673). (p. 376)

9–13—*Atrypa independencis janesvillensis* Fenton and Fenton, n. subsp., Janesville, Iowa. 9, 10, Interior views of pedicle valves. 11, Internal view of a brachial valve (U. S. Nat. Mus. 84683). 12, Pedicle view of the holotype, a relatively immature specimen (U. S. Nat. Mus. 84682). 13, Brachial view of a larger, older shell (U. S. Nat. Mus. 84684). (p. 379)

14–16—*Atrypa independencis* Webster. 14, Pedicle view of an elongate specimen with fine plications; Independence, Iowa (Walker Mus. 25994). 15, Pedicle view of a shell with alate growth lamellae well preserved; Independence, Iowa (U. S. Nat. Mus. 84640). 16, Pedicle view of an exceptionally large, thick shell, once possessing strong lamellae; Big Bend, Johnson County, Iowa (U. S. Nat. Mus. 84687). (p. 377)



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ATRYPA INFLATA Webster

Plate 43, figures 1–7

Atrypa lineata var. *inflata* WEBSTER, *1921*, Am. Midland Nat., vol. 7, p. 19.

Shell small, oval to subcircular, usually wider than long; typically both valves convex, depth of pedicle equalling that of brachial valves in several specimens. Dimensions of holotype and another typical specimen: length of pedicle valve, 23.8, 23 mm.; length of brachial valve, 21.2, 22 mm.; thickness, 18, 17.7 mm., of which brachial valve occupies 10 and 11 mm. respectively; width, 24.6, 22 mm.

Pedicle valve with almost uniformly curved profile from beak to anterior margin; lateral slopes moderately convex or flattened, as is the broad, shallow sinus beginning near midlength and terminating in a blunt, poorly defined lingual extension. Cardinal area, for *Atrypa*, high, very moderately curved; false cardinal area present upon many specimens. Beak and umbonal region produced; growth lines of early neanic stages show depth of pedicle valve to exceed that of brachial. Foramen small, open throughout life.

Brachial valve with greatest convexity posterior to midlength; except marginally, fold not distinguished from general convexity of shell; cardinal extremities obtusely subangular or rounded; lateral and antero-lateral margins variable; on lateral and postero-lateral slopes convexity much reduced; latter rarely convex.

Surface marked by small, evenly arranged plications, increasing in size anteriorly and in number by bifurcation and implantation; 8 to 10 in 5 mm. at midlength, 7 at anterior margin.

Remarks.—The lingual extension and fold of *A. inflata* suggest those of the apparent variant of *A. lineata* from Bake-Oven, Illinois, already mentioned, but in neither the curvature of the valves nor characters of the beak does it conform to that shell. Since it seems probable that characters of the lingual extension in this genus are highly homoplastic, no close relationships based upon them alone may be assumed. Nor does it seem possible to follow Webster in regarding *inflata* as a subspecies of *A. lineata*. Doubtless the two species are derived from a common stock, and in part they are contemporaneous, but no intermediate forms have been found to link them. Rather, *A. inflata* seems to be a highly differentiated representative of a group which departed from the morphologic trend exhibited by *A. lineata* and *A. devoniana* at a time when the stock was represented by a form resembling *A. independencis* of the Cedar Valley.

Occurrence.—Upper Cedar Valley (Bloody Run substage): near Charles City and Nashua, Iowa.

Types.—Holotype, U. S. Nat. Mus. 78610; hypotypes, same, 84655, 84656.

ATRYPA SPINOSA LINDERI Webster

Atrypa spinosa var. *lindere* (*sic*) WEBSTER, *1921*, Am. Midland Nat., vol. 7, p. 20.

This was described as "a relatively small form, and a well marked western variety" of *A. spinosa* Hall, "much smaller and coarser ribbed than the typical forms of this species [*A. spinosa*] occurring in the Devonian of the Canadian northwest."

Three specimens among the supposed syntypes fail to show the characters specified, and appear not to come from the strata mentioned in the label, in Webster's handwriting, which accompanies them. One specimen only, a crushed, exfoliated brachial valve, resembles *A. spinosa* Hall; others are variants of the forms which we have described as *A. trowbridgei* (p. 376). It seems clear that in writing, Webster had before him certain small coarse shells from Iowa, which he contrasted with others, apparently variants of his own *A. planosulcata*, collected by Whittaker on the Hay River, and sent him by Dr. E. M. Kindle. We feel forced therefore, to conclude that the variety *linderi* is unrecognizable, and so to be abandoned.

Specimens labeled syntypes but not such. —U. S. Nat. Mus. 78589.

ATRYPA DEVONIANA Webster

Atrypa devoniana WEBSTER (part), *1921*, Am. Midland Nat. vol. 7, no. 1, p. 19, (not pl. 8, figs. 9–11).—FENTON and FENTON, *1924*, Mus. Geol. Univ. Michigan, Contr., vol. 1, p. 134, pl. 26, figs. 16–24.

Like *Atrypa waterlooensis*, this species shows such great variation that it may be considered by groups or "forms." Unlike that species its forms differ so greatly that no general description seems advisable here, though the characters of ornamentation specified under form A may be regarded as typical. Again specimens illustrating forms are regarded as hypotypes of the species.

Form A (Pl. 37, fig. 1).

Shell medium to large; width as great as length or, more typically, greater than length, especially where lamellae are preserved. Dimensions of two typical specimens without lamellae: length of both pedicle and brachial valves, 23.3, 24.6 mm.; width, 23.3, 25.3 mm.; thickness, 15, 18.2 mm.

Pedicle valve quite convex in early stages; lateral areas slope gently from central convexity to margins; in some specimens, especially those whose lamellae are preserved, a concavity is formed in the lateral regions; sinus appears 13 to 15 mm. from the beak, broad and shallow, 7.5 to 10 mm. wide in typical shells.

Brachial valve highly convex; lamellae, laterally, extend outward and recurve; fold indistinct except near anterior margin; cardinal areas rounded, hinge line straight; beak hidden by recurved beak of pedicle valve: indistinct furrow on umbo.

Surface marked by distinct plications that increase in number by both bifurcation and implantation; 7 to 9 in 5 mm. at 10 mm. from pedicle beak; growth lines numerous, especially near anterior margins.

Occurrence.—*Spirifer* zone of the Hackberry stage: Floyd and adjoining counties, Iowa.

Types.—Syntypes, U. S. Nat. Mus. 78605, 78612; hypotypes, same, 84666.

Form B (Pl. 37, figs. 2–6; Pl. 39, fig. 12).

Atrypa devoniana, form undescribed, FENTON and FENTON, *1932*, Am. Midland Nat., vol. 13, pl. 21, fig. 5.

Shell small, about half the size of a mature specimen of form A; typically wider than long; hinge line almost straight; pedicle beak projects beyond brachial umbo. Dimensions of two specimens without lamellar projections: length of pedicle valve, 11, 13.9 mm.; length of brachial valve, 10.5, 13.6 mm.; width, 12.5, 13.8 mm.; thickness, 7.4, 8.5 mm.

Pedicle valve highly convex, in some cases equalling or exceeding convexity of brachial valve; shell outline varies greatly according to development of lamellae; when these are preserved, shell much wider than long; beneath lamellae, cardinal extremities rounded, as are the extremities of lamellae themselves; with lamellae removed, lateral areas

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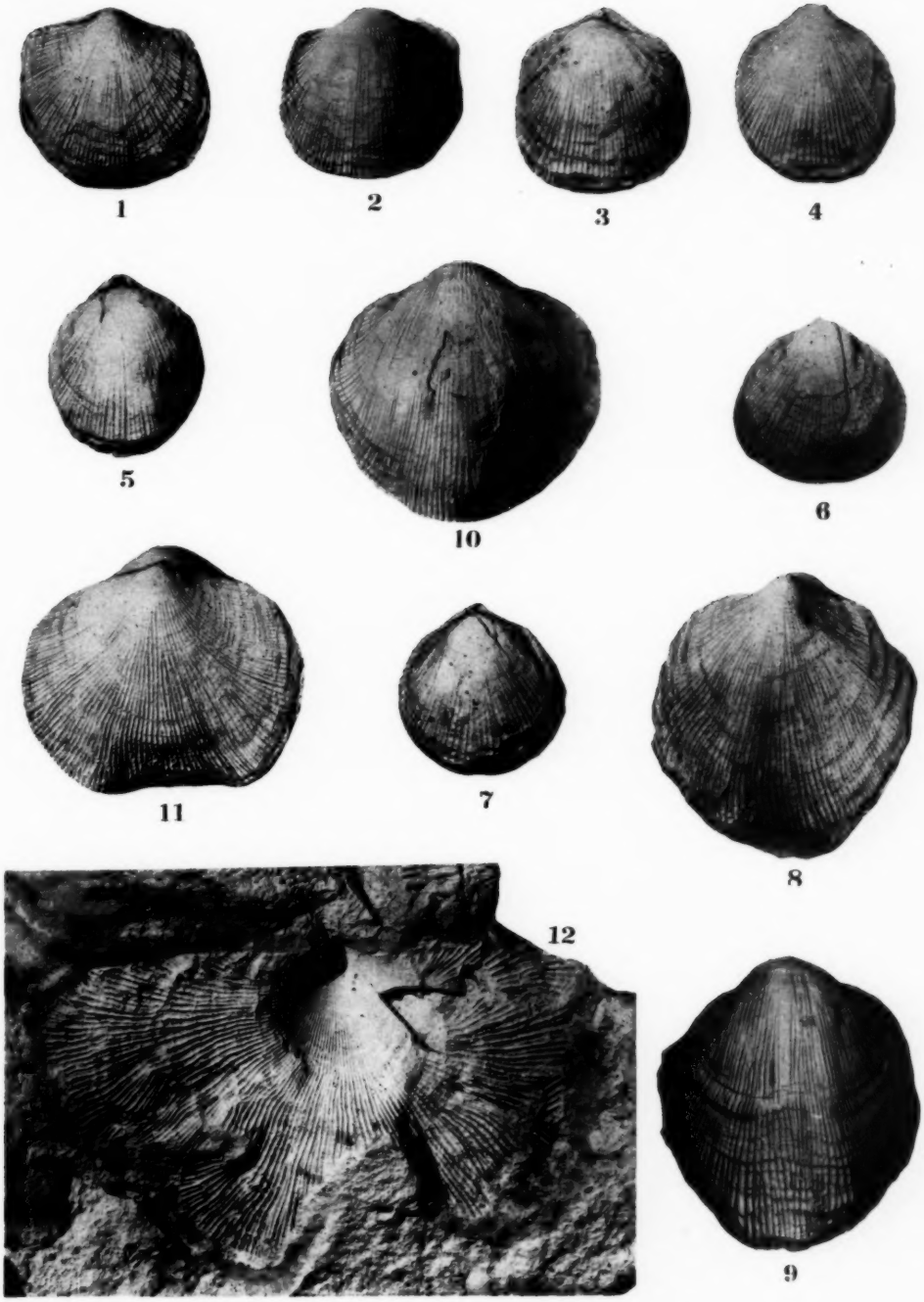
EXPLANATION OF PLATE 43

FIGS. 1–7—*Atrypa inflata* Webster. 1, 2, Pedicle and brachial views of a wide-shelled specimen; near Nashua, Iowa (U. S. Nat. Mus. 84656). 3, Brachial view of the holotype; Charles City, Iowa (U. S. Nat. Mus. 78610). 4, 5, Pedicle and brachial views of a narrow specimen; 6, 7, pedicle and brachial views of a wide specimen; Scripture Quarry, near Charles City, Iowa (U. S. Nat. Mus. 84655). (p. 381)

8, 9—*Atrypa lineata* Webster, pedicle and brachial views of a narrow highly convex hypotype; near Charles City, Iowa (U. S. Nat. Mus. 84689). (p. 379)

10, 11—*Atrypa lineata* Webster, variant, brachial and pedicle views of a specimen from Andalusia, Illinois (U. S. Nat. Mus. 9214). (p. 380)

12—*Atrypa independencis* Webster, impression of a pedicle valve bearing very broad, alate lamellae, typical of "*A. expansa*" Webster; Independence, Iowa (U. S. Nat. Mus. 84720). (p. 377)



Fenton and Fenton, Devonian Brachiopods

either slope gently from umbo to margins, or are flattened; sinus varies in width and appearance according to age of shell. Brachial valve in most cases more convex than pedicle; fold ranges from low, indistinct elevation to abrupt, rounded one; slight median furrow appears umbonally, in a few specimens continuing to margin.

Surface marked by plications, 7 to 10 in 5 mm. at 10 mm. from beak; increase by bifurcation and implantation.

Remarks.—Its uniformity of characters, restricted range and association with other organisms not showing peculiarities that might be regarded as environmental in origin indicate that this diminutive form probably was hereditary.

Occurrence.—Hackberry (upper Cerro Gordo, zonules 33–34 of Belanski): Hackberry Grove and Bird Hill, 4 miles west of Rockford, Iowa.

Hypotypes.—U. S. Nat. Mus. 84667.

Form C (Pl. 37, figs. 7, 8).

Shell small, valves longer than wide, about equally convex. Dimensions of larger type: length of pedicle valve, 11.4 mm.; length of brachial valve, 10.1 mm.; width, 9.6 mm.; thickness, 4.2 mm.

Pedicle valve convex to midlength; lateral and anterior areas sloping gently to margins; no sinus; beak very prominent, deltidial plates generally preserved; foramen large. Brachial valve similar to pedicle in general appearance; beak concealed; slight furrow on umbo. Surface with plications comparable to those in equivalent areas of *A. devoniana*, form A, though finer; 10 in 5 mm. at 10 mm. from pedicle beak; growth lamellae comparatively few.

Remarks.—The two specimens at hand were considered a new species by C. L. Webster, but their resemblance to the familiar form A of his species *devoniana* seems to justify the rank given them here.

Occurrence.—Hackberry (uppermost Cerro Gordo substage): Floyd and Cerro Gordo counties, Iowa.

Hypotypes.—U. S. Nat. Mus. 84665.

ATRYPA DEVONIANA DECRESCENS Fenton and Fenton, n. subsp.

Plate 38, figures 4–6

Shell small, slightly longer than wide, with maximum width near midlength; cardinal extremities considerably rounded. Dimensions of three specimens: length of pedicle valve, 16.4, 18, 20 mm.; length of brachial valve, 15.5, 17.5, 19 mm.; maximum width, 15.4, 16.6, 17.7 mm.; width at the hinge line, 11.7, 12, 12 mm.; thickness, 10.7, 12.3, 13.4 mm.

Pedicle valve one-fourth to one-third total thickness of shell; highly convex umbonally in adults; in late neanic stages deeper than brachial valve; cardinal areas angular in large shells, but growth lines show them rounded in young ones; sinus slightly developed in some specimens; beak prominent, slightly recurved; foramen small. Brachial valve highly convex from umbo to anterior margin; fold slightly developed. Surface marked by fine plications, 9 to 12 in 5 mm. at 10 mm. from pedicle beak.

Occurrence.—Hackberry (upper Cerro Gordo substage): Floyd and Cerro Gordo counties, Iowa. Probably the basal Owen substage as well.

Types.—Holotype, U. S. Nat. Mus. 84664; paratypes, same, 84662, 84663. An intermediate specimen (Pl. 38, figure 6) is U. S. Nat. Mus. 84648.

ATRYPA OWENSIS Webster

Atrypa owensis WEBSTER (part), *1921*, Am. Midland Nat., vol. 7, p. 14 (not pl. 8, figs. 12–14).—FENTON and FENTON, *1924*, Mus. Geol. Univ. Michigan, Contr., vol. 1, p. 141, pl. 26, figs. 9–11.

Form A. (Pl. 42, figs. 1, 2).

Shell small, longer than wide, with slightly rounded cardinal extremities. Dimensions of a syntype and a hypotype: length of pedicle valve, 10.5, 13.4 mm.; length of brachial valve, 9.5, 12 mm.; width, 10, 12.6 mm.; thickness, 5.5, 10.7 mm.

Pedicle valve more convex than brachial, with greatest convexity generally posterior to midlength; beak produced,

slightly recurved; hinge line forms a broadly obtuse angle, or is straight. A mesial elevation in neanic stages of most specimens; gerontic ones with very shallow sinuses and slight lingual extensions. Brachial valve slightly convex; marginally (in gerontic specimens) it bears an indistinct fold. Surface marked by plications nearly uniform in size from umbo to margin, typically increasing by bifurcation, though also by implantation; 7 in 5 mm. at 10 mm. from brachial beak.

Remarks.—Our illustrations of 1924 were drawn from photographs made for, but not published with Webster's original paper. They represent three specimens, not one, as stated in the explanation. None of these are among the types preserved in the National Museum. Though the latter are poorly preserved, they serve to redefine the species and determine its variants.

Occurrence.—Hackberry (lower Owen substage): Owen's Grove, Cerro Gordo County, Iowa.

Types.—Syntypes, U. S. Nat. Mus. 84740; hypotype, same 84696.

Form B (Pl. 42, figs. 3–6).

Shell about equal in width and length. Dimensions of a typical specimen: length of pedicle valve, 14.6 mm.; length of brachial valve, 12.7 mm.; width, 14.6 mm.; thickness, 7.6 mm.

Pedicle valve less convex than that of form A, apparently lacking a sinus; beak less recurved in mature shells. Brachial valve shows convexity approaching that of young stages of form A, with flattened postero-lateral regions. Plications offer no distinguishing characters.

Occurrence.—Hackberry (lower Owen substage): Owen's Grove and elsewhere, Cerro Gordo County, Iowa.

Types.—Syntypes, U. S. Nat. Mus. 78611; hypotypes, same 84697.

ATRYPA SUBHANNIBALENSIS Webster

Atrypa subhannibalensis WEBSTER (part), *1921*, Am. Midland Nat., vol. 7, p. 18 (*not* pl. 8, figs. 15, 16).—FENTON and FENTON, *1924*, Mus. Geol. Univ. Michigan, Contr., vol. 1, p. 145, pl. 27, figs. 1–3.

No specimens have been found which further elucidate the characters of this species. The "narrower and longer" specimen which we mentioned in 1924 seems better referable to *A. rockfordensis elongata* Webster of an earlier paper (*Am. Midland Nat.*, vol. 13, pl. 23, fig. 1, 1932) and has been so illustrated. It strengthens the apparent gerontic relationship of *A. subhannibalensis* to *A. rockfordensis.*

Occurrence.—Hackberry (lower Owen substage): Owen's Grove, Cerro Gordo County, Iowa.

Types.—Holotype not traced, though plastotypes are preserved in the U. S. Nat. Mus. and Walker Mus., Univ. Chicago. Paratype, U. S. Nat. Mus. 78584.

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3. The term *hypotype* is used throughout this paper in the sense in which we formerly have used *plesiotype.* This follows the recommendation of Frizzel (*Am. Midland Nat.*, vol. 14, pp. 640, 653, 662, 1933), who finds plesiotype both synonym and homonym.
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JOURNAL OF PALEONTOLOGY, VOL. 9, NO. 5, PP. 385–389, PLS. 44–46, JULY, 1935

A PLESIOSAUR FROM THE UPPER CRETACEOUS OF MANITOBA

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ABSTRACT

Trinacromerum kirki Russell, n. sp., is the first member of the family Polycotylidae to be recorded from Canada by a considerable part of the skeleton, and is the most adequately known Canadian plesiosaur.

The specimen forming the subject of the present contribution was discovered by Mr. B. Mayhew, of Treherne, Manitoba. Brought to the notice of the Manitoba Natural History Society, the bones were collected, during the fall of 1932 and the spring of 1933, by the late Professor S. R. Kirk, assisted by Messrs. H. W. Rand and P. H. Stokes. Considerable preparation was accomplished by Professor Kirk and his students, but following his untimely death in the spring of 1934, little progress was made. Late in the fall of 1934 the Manitoba Museum Association obtained loan of the writer's services to complete the preparation and mounting of the specimen. On November 10 it was placed on exhibition in the Manitoba Museum at Winnipeg. The writer is indebted to the Manitoba Museum Association for the privilege of studying and describing this interesting fossil.

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Order SAUROPTERYGIA

Family POLYCOTYLIDAE

Genus TRINACROMERUM Cragin

TRINACROMERUM KIRKI Russell, n. sp.

Plates 44–46

Trinacromerum sp., KIRK, *1933*, The Question Mark (Univ. Manitoba), vol. 1, no. 1, pp. 6–10, 1 fig.

Type.—Manitoba Museum, Winnipeg; incomplete skeleton, from Assiniboine beds (Benton), section 16, township 9, range 10, west of 1st meridian, Assiniboine river, northwest of Treherne, Manitoba; found by B. Mayhew.

Specific characters.—About the size of *T. bentonianum* Cragin. Ilium flattened-ovoid in cross section, not rounded; pubis and ischium flat, not concave, and with oblique sutural truncation; ischium markedly elongate posteriorly.

Description.—Specimen lacking all trace of skull and cervical vertebrae. Present 14 distorted dorsal vertebrae, 17 from caudal series; a number of fragmentary ribs. Pectoral girdle represented only by coracoids, right one fragmentary, both lacking preglenoid portion. Pelvis complete, well preserved. Both humeri and femora present; right paddles more or less complete; left mostly absent.

Dorsal vertebrae (Pl. 44, figs. 1, 2) so distorted that they cannot be arranged in sequence with any certainty; 8 centra,

presumably from anterior part of series, strongly sheared right side ahead of left; remainder sheared in opposite direction; distortion suggesting dissociation of vertebral column prior to entombment. All centra subcylindrical, moderately amphicoelous; sides shallowly concave, ventral surface almost straight from front to rear. Neural canal of moderate size; neural spine high, thin from side to side, broad from front to rear. Transverse processes rather long, arising at base of neural spine, projecting upward and outward; on some vertebrae flattened-ovoid in cross section, in others subcylindrical, these shapes corresponding to form of rib heads, flattened on the more anterior ribs, subcircular or subquadrate on posterior members of series. Zygapophyses slender, prezygapophyses well separated from each other, postzygapophyses set close together; articular facets of zygapophyses approximately horizontal on most vertebrae.

Three of caudal vertebrae from anterior portion, remainder forming continuous series almost to tip. In anterior caudals (Pl. 44, fig. 3) centrum subquadrate, somewhat broader than high. Parapophyses short, pointed, somewhat compressed from front to rear; spine narrow, moderately stout, projecting almost straight upward; well-developed chevron facets on both front and rear of centra. In series of posterior caudals (Pl. 44, fig. 4), centrum depressed-hexagonal, with large chevron facets behind, but mere emarginations in front; transverse processes rather long, flattened dorsoventrally, expanded at base and extremity, not firmly united with centrum; neural arch small; spine blade-like, directed more backward than upward.

All of larger ribs (Pl. 44, fig. 5) with articular face of head elongate in plane of curvature of shaft. As articular ends of transverse processes in anterior dorsal vertebrae are similarly elongate in horizontal plane, it seems certain that ribs curved considerably backward, rather than straight downward, as commonly represented.

Coracoids (Pl. 44, fig. 7) described from left one, as right is fragmentary and distorted; clavicular process missing; shape very similar to that in *T. osborni* (Williston) (*3a*), although a little more elongate relatively; foramina set close to median margin, may not have been completely closed; no sign of posterior thickening described by Cragin (*2a*).

Outline of humerus shown in accompanying figure (Pl. 46, fig. 1); head distinctly raised above great tuberosity, no intervening constriction; distal end with four distinct articular facets. Radius subquadrate, distinctly carinate along anterior side. Ulna smaller than radius, pentagonal. From four articular facets on humerus two supernumerary ossicles in radius-ulna series are deduced. Radiale resembling radius in shape but smaller. Next bone in series designated intermedium, although perhaps the centrale; irregularly hexagonal. Ulnare subquadrate rather thin; in addition to four principal articular faces, small proximal facet on posterior side, indicating presence of small ossicle filling triangular space between ulnare and first supernumerary epipodial. First carpale a miniature of radiale, not so sharply keeled anteriorly; second carpale subquadrate, with oblique truncation at antero-proximal angle; third carpale likewise subquadrate, both anterior angles truncated; various articulations of carpal elements shown in Pl. 46, fig. 1. First metacarpal subquadrate resembling radius, radiale and first carpale in being subtrigonal in

EXPLANATION OF PLATE 44

FIGS. 1–7—*Trinacromerum kirki* Russell, n. sp. 1, Anterior dorsal vertebra, anterior view; 2, posterior dorsal vertebra, anterior view; 3, anterior caudal vertebra, anterior view; 4, caudal vertebra, about 15th from extremity, anterior view; 5, portion of anterior dorsal rib; 6, segment of ventral rib; 7, coracoids, as preserved, the right one partly restored, dorsal view. All figures ×3/20.

Russell, Cretaceous Plesiosaur

transverse section; anterior keel very blunt. Second metacarpal a peculiar shaped bone, as described by Williston (*3b*), phalangiform but with proximal end pyramid-shaped; remaining metacarpals phalangiform, the fifth, which is missing, displaced proximally to align with carpalia. Only three phalanges preserved, of typical spool-like shape, subquadrate in cross section. All bones of front limb distal to humerus and corresponding elements of hind limb so shaped that ventral side is almost an exact mirror image of dorsal, of great convenience in restoration of missing parts of opposite limb.

Ilium (Pl. 45) short, blade-shaped, curving backward and upward, inclined somewhat inward; base expanded, with large, oblique articular face for pubis, smaller facet for femur; shaft ovoid in cross section, flattened from side to side; apex not much expanded, a little roughened internally, but with no very distinct articular face for sacral ribs. Pubis thin and flat; in outline like pubis figures by Williston (5) for *T. osborni*, but comparison with photographs of type of that species (*3c*) shows less resemblance; external margin slightly sinuous, instead of simply concave, a resemblance to *T. bentonianum* rather than *T. osborni;* anterior margin irregularly concave; medial margin obliquely truncated, as in *T. osborni;* most striking difference from pubis of that species is marked backward prolongation of medial margin, ending in a truncated process, evidently connected to opposing process of ischium by cartilage; this cartilaginous bar, with its fellow, formed a median division of the pubo-ischiatic vacuity. Ischium long, blade-like; like the pubis, resembling Williston's figure for *T. osborni* but not outline figure (*3d*) originally given (these two figures differ so markedly that two different specimens, or possibly even species, appear to be represented); in present specimen symphysial margin obliquely truncated, like that of pubis; evidently in life these bones were orientated to slope gently to midline; forward extension of antero-medial angle of ischium noted above; right ischium shows impressions of vertebral centra crushed against it.

Femur (Pl. 46, fig. 2) closely resembling humerus, slightly larger, but not appreciably more slender; head a little broader, not as much elevated; great trochanter not as broad as great tuberosity of humerus; like humerus, femur bears four distinct articular facets at distal end. Remaining bones of hind limb present only on right side; tibia like radius in shape; fibula like ulna, slightly more elongate; posterior to fibula, first supernumerary of this row, basically triangular in outline, with distal and posterior angles truncated; Behind this again, second supernumerary, elongate-subtrigonal in shape, keeled on posterior side; tibiale resembling radiale, less acutely keeled; "intermedium" like bone so called in manus, but proportionally thicker; fibulare like ulnare, with postero-proximal articular facet more oblique; this facet articulating with distal end of supernumerary tarsal, a small, thick bone, subtrigonal in cross section, truncated obliquely at both extremities; this supernumerary also articulating with fibula and first supernumerary epipodial; first tarsale a miniature of tibiale, not so produced anteroproximally; second tarsale like second carpale, but thicker; third tarsale like third carpale, without articular surface for third metatarsal; first to fourth metatarsals resemble corresponding metacarpals closely; fifth metatarsal obliquely phalangiform in shape, subtrigonal in cross section, with a large inner facet near proximal end for articulation with third tarsale; phalanges like those of manus. As arranged by Kirk from their position in the matrix, there are 3 preserved of the third digit, 6 in the fourth, and 6½ in the fifth; remainder have been restored by the writer from comparison with *T. osborni*.

Measurements of skeleton

	mm.
An anterior dorsal vertebra, slightly distorted:	
Length of centrum	64
Width of centrum	96
A posterior dorsal vertebra (Pl. 44, fig. 2):	
Total height	202
Height of centrum	92
Width of centrum	87
Anterior caudal vertebra (Pl. 44, fig. 3):	
Height of centrum	77
Width of centrum	86
Width between extremities of transverse processes	130
Median caudal vertebra (Pl. 44, fig. 4):	
Height of centrum	42
Width of centrum	82
Width between extremities of transverse processes	205
Height of spine	81
Left coracoid, length as preserved	710
Greatest width	432
Right humerus, length	455
Width at head	121
Width at distal end	+222
Right radius, length	70
Width	115
Right ulna, length	68
Width	84
Right radiale, length	48
Width	79
Right "intermedium," length	51
Width	65
Right ulnare, length	49
Width	55
Right 1st carpale, length	36
Width	57
Right 2nd carpale, length	45
Width	52
Right 3rd carpale, length	53
Width	39
Right 1st metacarpal, length	42
Width	43
Right 2nd metacarpal, length	59
Width	34
Right 3rd metacarpal, length	59
Width	30
Right 4th metacarpal, length	58
Width	34
Right 1st phalanx, digit 4, length	57
Width	33
Right pubis, length	486
Width	445
Right ischium, length	602
Width	299
Right ilium, length	295
Width at lower end	65
Right femur, length	473
Width at head	135
Width at distal extremity	236
Right tibia, length	73
Width	111
Right fibula, length	74
Width	89
Right 1st supernumerary epipodial, length	63
Width	51
Right 2nd supernumerary epipodial, length	54
Width	29
Right tibiale, length	44
Width	77
Right "intermedium," length	59
Width	65
Right fibulare, length	50
Width	57
Right 1st tarsale, length	37
Width	56
Right 2nd tarsale, length	47
Width	56
Right 3rd tarsale, length	52
Width	42
Right supernumerary tarsale, length	41
Width	19
Right 1st metatarsal, length	47
Width	43
Right 2nd metatarsal, length	57
Width	35
Right 3rd metatarsal, length	60
Width	35
Right 4th metatarsal, length	62
Width	34
Right 5th metatarsal, length	62
Width	37
Right proximal phalanx, digit 3, length	50
Width	35
Right proximal phalanx, digit 4, length	57
Width	34
Right proximal phalanx, digit 5, length	62
Width	38

Remarks.—The present specimen appears to be closest to *Trinacromerum bentonianum* Cragin (1, 2, 4*a*) being almost identical in certain dimensions, and only slightly smaller in others. There are,

EXPLANATION OF PLATE 45

Trinacromerum kirki Russell, n. sp. Pelvis, dorsal view; the ilia, in natural articulation, would be directed toward the observer; ×3/20.

EXPLANATION OF PLATE 46

FIGS. 1, 2—*Trinacromernum kirki* Russell, n. sp. 1, Right front limb, dorsal view, partly restored; 2, right hind limb, dorsal view, partly restored, the posterior curvature shown probably being too great. Both figures ×3/20.

Russell, Cretaceous Plesiosaur

Russell, Cretaceous Plesiosaur

however, certain osteological differences, especially in the pelvis, which appear to the writer as of specific rank. Unfortunately, this portion of *T. bentonianum* has not been figured, so that the differences may not be as great as would appear from the descriptions. However, on the basis of material at hand, the Manitoba plesiosaur does not appear referable to *T. bentonianum*, and is therefore made the type of a new species, *T. kirki*.

The size of this species is almost twice that of *T. osborni* (3*e*), the best known member of the genus. Certain resemblances and differences between the two species have been noted above. *T. anonymum* Williston (3*f*, 4*b*) is not much larger than *T. osborni*, and the femur and humerus are rather different from those of *T. kirki*. *T. latimanus* Williston (4*c*) is also smaller than *T. kirki*, and differs in having the distal extremity of the humerus greatly expanded.

The humerus of *T. kirki* is rather like that of *Polycotylus latipinnis* Cope (4*d*). The distinction between the genera *Polycotylus* and *Trinacromerum* is not yet clear; apparently the presence or absence of a second supernumerary epipodial is not a satisfactory distinction. This is a problem for workers having access to extensive collections of plesiosaurs.

The present specimen is of interest as the most adequately known Canadian plesiosaur, and as the first definite record of the Polycotylidae from Canada.

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A NEW ANTILOCAPRID FROM THE UPPER PLIOCENE OF IDAHO

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ABSTRACT

Ceratomeryx prenticei Gazin, n. gen. and sp., is described from the Hagerman lake beds, where it is associated with *Plesippus shoshonensis* Gidley.

Among the fossil vertebrates collected near Hagerman, Idaho, by the 1934 Smithsonian expedition to southern Idaho are remains of an interesting four-horned antilocaprid apparently distinct from the previously known members of the family. The specimens were encountered by Mr. George F. Sternberg while excavating horse material in a small prospect-quarry one hundred feet or more to the southeast of the principal quarry, from which were obtained abundant remains of the extinct horse *Plesippus shoshonense* Gidley.

This paper is published by permission of the Secretary of the Smithsonian Institution, and was received by the editor March 29, 1935.

Genus CERATOMERYX Gazin, n. gen.

Four supra-orbital horns as in *Tetrameryx;* anterior horns in adult stage much larger than posterior pair and directed backward more than in *Tetrameryx;* horns transversely compressed and set inward from margin of orbit. Orbit apparently forward in position with respect to dentition. Teeth hypsodont; deciduous upper premolars and first two molars as in *Antilocapra americana*. Basi-occipital narrow and audital bullae inflated postero-externally.

Etymology: κερατος, horn; μηρυξ, ruminant.

CERATOMERYX PRENTICEI Gazin, n. sp.

Text-figure 1

Types.—Holotype, cranial portion of skull, U. S. Nat. Mus. 13760, and first to fifth cervical vertebrae; paratype, immature skull, U. S. Nat. Mus. 13761, and an associated right hind limb.

Horizon and locality.—Hagerman lake beds, T. 7 S., R. 13 E., near *Plesippus* quarry, Hagerman, Idaho.

Name.—For Mr. Sydney Prentice, in compliment to his skill in depicting fossil vertebrates.

Specific characters.—Size of skull appreciably smaller than in *Antilocapra americana*. Horns much smaller than in species of *Tetrameryx;* saddle between anterior and posterior horn low in adult. Occipital crest well developed; median ridge on occiput broad, prominent.

Material.—Representing this new antilocaprid are portions of two or possibly three individuals. The type specimen consists of an adult, incomplete cranium exhibiting the horned frontal region and the occipital and basicranial areas, with which in a position of articulation were the first five cervical vertebrae. The maturity of the specimen is indicated by the development of the occipital crest

and the extent to which sutures have been obliterated. A trace on the fronto-lachrymal suture can be discerned on the left side, and the parieto-squamosal sutures were probably not fully ankylosed, as dorso-ventral crushing has caused the cranium to fold along these lines. However, these sutures can be seen in fully adult specimens of *Antilocapra americana*. A second, less mature individual, obtained not more than four or five feet from the older animal and at the same level, includes a nearly complete skull in close association with an articulated hind limb. The young skull, though badly crushed, exhibits the horns and an immature dentition. The snout anterior to the teeth is missing and the audital bullae are damaged. The dentition on both sides includes the three deciduous premolars and the first two permanent molars, the last of which is nearly unworn. A third individual may be represented by a series of vertebrae from the axis to the fourth dorsal and several ribs found in the *Plesippus* quarry.

Description.—Ceratomeryx prenticei is apparently distinct from other antilocaprids in the characters of the horns. It differs from *Antilocapra americana* as do the species of *Tetrameryx* (3, 5, 6) in having two spikes rising above each orbit. The anterior pair in the type are not directed forward as in *Tetrameryx*, are considerably larger than the posterior pair; and both pairs are noticeably flattened transversely. In *Tetrameryx* the horns are much larger in the adult stage, less flattened, and the posterior pair is as large or larger than the front pair. Moreover, the horns in the Hagerman form are set distinctly inward from the margin of the orbit, and appear to recurve inward slightly in the anterior view.

In the distorted immature skull, No. 13761, the two pairs of horns are small, transversely flattened, but nearly equal in size, resembling on a small scale and in lateral view the horns of the type of *Tetrameryx conklingi* Stock. The orbit in the immature skull is distinctly farther forward than in specimens of *Antilocapra americana* of comparable age. The anterior margin of the orbit is above approximately the middle of the second molar, whereas in *Antilocapra* it is above the posterior portion of the erupting crown of M^3. The relative position of the orbit is suggested in the type specimen by the elongate zygomatic process of the squamosal.

FIG. 1—*Ceratomeryx prenticei* Gazin, n. gen. and sp. Cranial portion of skull, holotype specimen, U. S. Nat. Mus. 13760, lateral and antero-dorsal views, ×1/2. Hagerman lake beds, upper Pliocene, Idaho. Drawing by Sydney Prentice.

The characters of the basicranial region of *Ceratomeryx* clearly distinguish

it from *Antilocapra* and for the most part ally it with *Tetrameryx*. The basi-occipital is narrower between the relatively large bullae and the latter are inflated postero-externally, leaving a somewhat shorter external audital tube and a narrower gap between the bulla and the paroccipital process. Also, the bony tube surrounding the hyoid process is closed posteriorly for a greater distance ventrally along the antero-external surface of the bulla.

The lambdoidal crests and the supra-occipital are outstanding as is the broad median occipital ridge, but the prominence of these parts may be due in part to dorso-ventral crushing that has affected this portion of the cranium.

The teeth, with the exception of a somewhat deeper median lingual fold on Dp^3, in the immature skull closely resemble those in *Antilocapra americana* and are nearly identical in size, although the skull appears relatively small for the stage represented by the teeth.

The cervical vertebrae belonging to the type are nearly as long as in *Antilocapra americana* but are noticeably more slender. The transverse processes are not well preserved but apparently do not project laterally to the extent seen in the modern type; also the posterior portion of the ventral keel of the centrum appears better developed in the fossil. A second series of vertebrae from the axis to the fourth dorsal, found in the *Plesippus* quarry, are of the antilocaprid type but distinctly smaller than in the type specimen of *Ceratomeryx prenticei*. The epiphyses of the centra are fused, but the line of contact in several places has not been obliterated. These vertebrae may represent a younger individual of *C. prenticei* or may possibly represent a form such as *Capromeryx*.

The femur and tibia of the articulated hind limb associated with the immature skull closely resemble those of young *Antilocapra americana*. Detailed comparisons are not practicable since these bones are not fully developed. The epiphyses are insecurely attached. The cannon bone, however, is shorter and broader at the ends than in an individual of *A. americana* of comparable age. The tarsus apparently shows no distinguishing characters, but the phalanges are more robust than in the young *A. americana* skeleton with which these comparisons are made.

Remarks.—Ceratomeryx prenticei is clearly an antilocaprid and appears to be more closely related to *Tetrameryx* than to *Antilocapra americana* or species of *Capromeryx*. The occurrence of *C. prenticei* in the upper Pliocene suggests that it may lie in or near an ancestral position to *Tetrameryx* as known from the Dallas sand pits and caves in New Mexico and Arizona. *Antilocapra* is presumably not descended from *Ceratomeryx* unless we assume a complete reduction of the posterior horns and a subsequent tendency toward bifurcation of the anterior pair. It seems more probable that the condition in *Antilocapra* is a modification of the horn structure seen in *Sphenophalos*, as outlined by Furlong (2), and that the posterior horns in *Ceratomeryx* may have originated as a new structure at some earlier Neocene stage. There remains the possibility that the horns in *Ceratomeryx* are homologous with the prongs in *Sphenophalos* and that in the line of *Ceratomeryx* the beam was not developed, or was early reduced.

Proantilocapra platycornea (1) from the lower Pliocene of Nebraska has been suggested by Barbour and Schultz to occupy a position in or near the line of *Antilocapra*. The outstanding characters of the horn in the type of *P. platycornea* are its transverse flatness or wedge shape and the enlarged blunt tip, the latter being difficult to interpret.

An earlier record than that of the occurrence of *Ceratomeryx* in beds presumed to be a part of the Idaho formation is that of *Neotragoceras lindgreni* Merriam (4). The specimen is an incomplete right horn-core showing a portion

of the brain cavity and a segment of the orbital surface of the frontal. The horn-core appears to have been directed backward to a marked degree, distinguishing it from *Antilocapra* and suggesting a relationship with bovids such as *Oreamnos*. The possibility of the specimen representing the posterior horn of a robust four-horned type such as *Tetrameryx shuleri* is not eliminated.

Measurements (in millimeters) of skull of *Ceratomeryx prenticei* (U. S. Nat. Mus. 13760)

Width of skull between posterior margins of orbits, estimated	127
Distance between outer surfaces of anterior horns near base	86.2
Distance between outer surfaces of posterior horns	74
Approximate length of anterior horns	50
Approximate length of posterior horns	17
Antero-posterior diameter of anterior horns about one-half inch above base	17.5
Transverse diameter of anterior horns about one-half inch above base	10
Distance from anterior surface of anterior horn to posterior surface of posterior horn	42
Distance from line between anterior margins of horns near base to supra-occipital	87
Depth of occiput from supra-occipital to dorsal margin of foramen magnum	32
Width of occiput across periotics	73.5
Width across occipital condyles	43.5
Least width of basi-occipital between bullae	16

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LARVAL STAGES OF TRILOBITES FROM THE MIDDLE CAMBRIAN OF ALABAMA

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ABSTRACT

In very young larvae of trilobites from the Middle Cambrian of Alabama the positions of the free-cheeks, eyes, and palpebral lobes differ in some respects from those described by earlier students. It appears that the eyes develop later than the facial suture, palpebral lobes, and free-cheeks, and that instead of migrating over the margin from the ventral side, they are formed on the free-checks during some moult.

It is now generally known that the larval stages of trilobites are minute ovoid or subquadrate bodies, usually less than one millimeter in length, in which the head portion predominates. They present very little likeness to the adult, to which, however, they are traceable through a series of transitional forms.

Barrande (1), first demonstrated the metamorphoses of trilobites in 1849. Similar observations have been made upon a number of different genera by Ford (2), Walcott (3, 4, 5), Matthew (6, 7, 8), Salter (9), Callaway (10), Raymond (11), Beecher (12), Strand (13), and Raw (14, 15). The general facts of the ontogeny have thus become well established, but the main features of the youngest stages are not so well understood.

In the present paper, the writer describes a series of changes in some of the youngest larvae of trilobites, in what has been called the "protaspis" stage by Beecher (12). The changes shown by these protaspides are compared with those described by some of the earlier workers.

The material upon which these observations were made, was collected by Prof. P. E. Raymond during the Shaler Memorial Expedition of 1921, at Moshat's Cross Roads, east of Center, Cherokee County, Alabama. The material consists of weathered fragments of the Conasauga formation, of Medial Cambrian age. The rock is a cherty, sandy limestone, weathered to such an extent that most of the protaspides are very poorly preserved. The exact species represented in these youngest stages is not definitely known, though they are thought to be *Blainia gregaria* Walcott because of association with a great abundance of fragments of that species.

The figured specimens are deposited in the Museum of Comparative Zoology, Harvard University.

Acknowledgments.—I am indebted to Dr. P. E. Raymond, of Harvard University, under whose supervision this report was prepared, and to Dr. J. A. Cushman, also of the University, for photographing the shells at the Cushman Laboratory

for Foraminiferal Research. I am especially grateful to my wife for drawing the shells.

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DESCRIPTION OF THE LARVAL SPECIMENS

PLATE 47, FIGURES 1*a*, *b*

Outline circular with a slight reentrant at the posterior end; axial lobe very indistinct, broader at the anterior margin; facial suture convex forward from the anterior furrow of the axial lobe, meeting the lateral margin near the anterior end; eye ridges and palpebral lobes poorly developed, but present, slightly posterior to the anterior margin; free cheeks developed only on the anterior margin, indicating a proparial type of head-plan in the form representing the earliest stage of the protaspis; pygidium not yet developed. Length, 0.35 mm.; width, 0.35 mm.

PLATE 47, FIGURE 2

Outline nearly circular, as in the preceding form; anterior margin with a slight invagination in the center, posterior margin showing a narrow reentrant; axial lobe indistinct with no evidence of lobation; facial suture developed as in the preceding form; eye-ridges distinct, palpebral lobes very distinct, located midway between the axial lobe and the lateral margin and at right angles to the axial lobe; pygidium not yet developed. Length, 0.38 mm.; width, 0.38 mm.

PLATE 47, FIGURE 3

Outline subquadrate, slightly longer than wide, anterior margin rounded on each side of a central reentrant, posterior end also marked by a central reentrant, lateral margins nearly straight; axial lobe indistinctly divided into five segments, the anterior of which is longer and wider than the others; occipital ring short; facial suture convex forward from the central part of the anterior segment, curving outward, meeting the lateral margin at a point one-fourth the distance between the anterior and posterior margins; eye-ridges present, palpebral lobes midway between axial lobe and lateral margin; pygidium rudimentary. Length, 0.47 mm.; width, 0.45 mm.

PLATE 47, FIGURES 4*a*, *b*

Outline similar to the preceding form, but with anterior margin broadly rounded; axial lobe faintly divided into five segments, the anterior one flattened at the anterior margin; facial sutures, eye-ridges, and palpebral lobes developed as in the preceding form; pygidium obscurely developed, but larger than the preceding form. The free-cheeks in this and the preceding form are developed only in the antero-lateral portion, indicating persistence of the proparial type of head-plan in the forms representing the earliest stages of the protaspis period. Length, 0.48 mm.; width, 0.46 mm.

PLATE 47, FIGURES 5*a*, *b*

Outline subquadrate, longer than wide, anterior margin broadly rounded, posterior forming a reëntrant on each side of the occipital ring; axial lobe distinctly divided into five segments, the anterior of which is long and flattened, posterior segments lobulate; facial suture extends from anterior margin backward to the eye-ridges, then curves outward and backward to the anterior portion of the lateral margin, distinctly separating the proparian free-cheeks from the fixed cheeks; eye-ridges indistinct, palpebral lobes well developed midway between the axial lobe and the lateral margin; pygidium missing. Length, 0.48 mm.; width, 0.46 mm.

PLATE 47, FIGURES 6*a*, *b*

Outline similar to that of preceding form; axial lobe distinctly divided into five segments, the anterior of which is much longer and wider than the others, occipital ring short, relatively small, and

projecting slightly posterior from the cephalic portion; facial suture well developed, passing from anterior margin around anterior portion of first segment, then curving outward and backward, meeting the lateral margin slightly posterior to the center; eye-ridges present, indistinct; palpebral lobes slightly anterior from the first side furrow and midway between the axial lobe and the lateral margins; pygidium short, with no visible segmentation. This form also has a proparial type of head-plan. Length, 0.62 mm.; width, 0.56 mm.

PLATE 47, FIGURE 7

Outline subrectangular, much longer than wide, anterior and posterior margins broadly rounded, lateral margins nearly straight, slightly curved outward in cephalic portion; axial lobe smooth, the occipital ring is the only visible segment in the cephalon; facial suture indistinct but appears to curve around the broad axial lobe, thence outward and backward, meeting the lateral margin near the center; eye-ridges indistinct, palpebral lobes also indistinct, but appear to be situated midway between the axial lobe and the lateral margin. Length, 0.85 mm.; width, 0.58 mm.

PLATE 47, FIGURES 8*a*, *b*

Outline subquadrate, wider than long; axial lobe smooth, elongate, inflated, and broader in the anterior portion with only one visible segment, the occipital ring; facial suture indistinct, but curves around broad anterior portion of axial lobe, thence outward and backward nearly to posterior margin; eye-ridges short, palpebral lobes antero-lateral in position, being nearer the lateral margin than in the preceding stages. This form also has a proparial type of head-plan, but is near the transition stage to the opisthoparial type. Length, 0.51 mm.; width, 0.72 mm.

PLATE 47, FIGURE 9

Outline and axial lobe similar to those of preceding form; facial suture short, beginning just anterior to the palpebral lobes, extending to a point just posterior to them; palpebral lobes near the antero-lateral margin, parallel to the outer curvature of the shell; free-cheeks absent, indicating an opisthoparial type of head-plan. Length, 0.85 mm.; width, 1.25 mm.

EXPLANATION OF PLATE 47

FIGS. 1–10—*Blainia gregaria* Walcott?, larval stages.

1*a*, *b*—Specimen showing youngest protaspis stage with obscure axial lobe, anterior free cheeks, and dorsal palpebral lobes. 1*a*, Drawing, ×43; 1*b*, photograph, ×48. (p. 395)

2—Specimen showing early protaspis stage with obscure axial lobe and dorsal palpebral lobes, ×40. (p. 395)

3—Specimen showing early protaspis stage with obscurely annulated axis, anterior free cheeks, and dorsal palpebral lobes, ×35. (p. 395)

4*a*, *b*—Specimen showing early protaspis stage with five distinct segments in axial lobe, and well-defined dorsal palpebral lobes, ×40. 4*a*, Drawing; 4*b*, photograph. (p. 395)

5*a*, *b*—Specimen showing intermediate protaspis stage with distinctly segmented axial lobe and dorsal palpebral lobes. 5*a*, Drawing, ×40; 5*b*, photograph, ×50. (p. 395)

6*a*, *b*—Specimen showing intermediate protaspis stage with distinctly segmented axial lobe, dorsal palpebral lobes, and short pygidium, ×34. 6*a*, Drawing; 6*b*, photograph. (p. 395)

7—Specimen showing late protaspis (?) stage with smooth axial lobe and well-developed pygidium, ×27. (p. 396)

8*a*, *b*—Specimen representing meraspid period with smooth axial lobe and antero-lateral palpebral lobes, ×45. 8*a*, Drawing; 8*b*, photograph. (p. 396)

9—Specimen representing meraspid period with well-defined antero-lateral palpebral lobes and absence of free-cheeks, ×25. (p. 396)

10—Specimen representing early holaspid (?) period with lateral palpebral lobes, ×13. (p. 397)

11—*Blainia gregaria* Walcott, adult specimen, ×3, after Walcott. (p. 397)

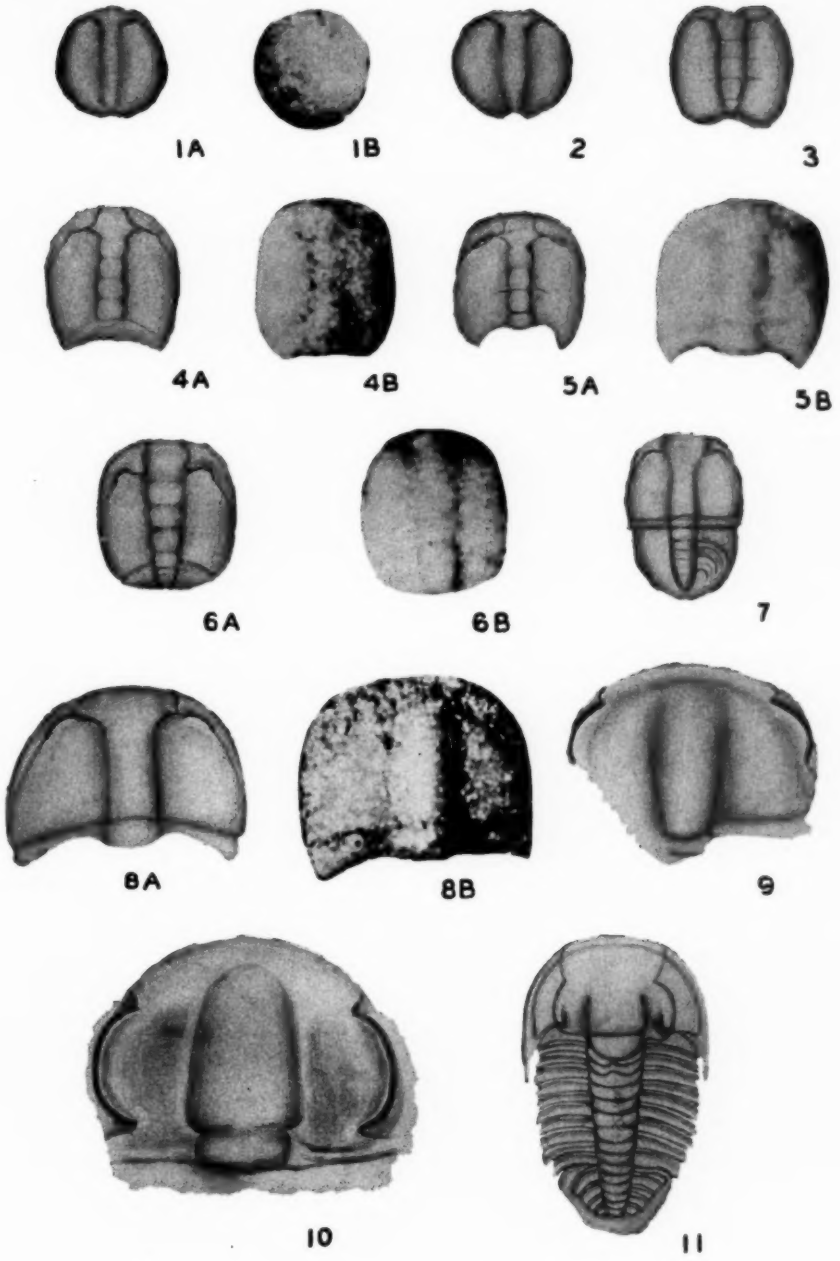

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PLATE 47, FIGURE 10

Outline subquadrate, wider than long; axial lobe broad, rounded, the short occipital ring being the only visible segment; facial suture short, being developed around the palpebral lobes as in the preceding form; palpebral lobes located on the lateral margin and parallel to it; free-cheeks absent, indicating an opisthoparial type of head-plan. Length, 2.30 mm.; width, 3.40 mm.

SUMMARY OF LARVAL DEVELOPMENT

The development of trilobites can be most conveniently divided into three successive periods by the stages marking, respectively, the beginning and the completion of the thorax (15). The earliest known stages, with all the cephalic segments and rudimentary post-cephalic segments, are included in the protaspid period. The second period, marked by the gradual formation of the thorax, is the meraspid period. The remaining period after the completion of the thorax is the holaspid period.

Of the forms described above, the first six belong to the protaspid period, probably also the seventh one. The stages represented by Plate 47, figures 8 to 10, inclusive, belong to the meraspid period, while that of Plate 47, figure 11, belongs to the holaspid period.

The following series of characteristics, changes, and modifications have been observed in the figured and described forms:

The eye-ridges and palpebral lobes are present on the dorsal side of the shell and behind the anterior margin even in the earliest stage of the protaspis period, as shown in Plate 47, figure 1. The eye-ridges and palpebral lobes are persistent throughout the protaspis period, the only changes being the backward and outward migration with increase in size of the cephalon. In the stages represented by the meraspid period, however, the eye-ridges disappear and the palpebral lobes are on the lateral margin.

The axial lobe in the forms which represent the earliest protaspis stages is characterized by an obscure, elongate axis somewhat broader at the anterior than at the posterior end. There are no indications of segmentation in the earliest forms, although it is thought to be present. In the forms representing the later protaspis stages, the axial lobe is divided into five well defined segments, with the frontal lobe much wider and longer than the others. The occipital ring is shorter than the anterior segments in the forms representing all stages, indicating greater specialization in the anterior portion of the cephalon. The segmentation is caused by an infolding of the shell to form the appendifers, according to Professor Raymond (oral communication). The segmentation disappears in the post-protaspis stages and is entirely absent in the adult.

The facial suture is obscurely developed in the earliest forms, but is very well developed in some of the later ones. In general, the facial suture passes from the anterior margin backward around part of the frontal lobe, then curves outward and backward in intimate association with the eyes and palpebral lobes. In forms representing the later stages of the protaspis the facial suture moves farther outward in the anterior portion as the width of the frontal lobe increases.

The free cheeks in the forms representing the earliest stages of the protaspis are developed only at the extreme anterior margin. In more advanced forms they are developed on the antero-lateral margin, and in the earliest forms of the meraspid period they are entirely lateral in position and support the genal spines. This migration of the free-cheeks from

an early anterior position to a late lateral position indicates that during the protaspid stages the cephalon is of the proparial type, whereas it becomes opisthoparial in the meraspid and holaspid periods.

The invagination of the posterior margin is a characteristic feature of the early stages of the protaspis. The anterior margin is also marked by an invagination in some, as shown in Plate 47, figures 2 and 3. The development of the posterior invagination is closely associated with the development of the pygidium, but the anterior invagination presents more of a problem. Professor Raymond suggests to the writer that the presence of both the anterior and posterior invagination is a possible indication that the bivalved shells of the Ostracoda were originally formed by the downfolding of the pleural lobes of the trilobite protaspis.

CONCLUSIONS OF EARLIER WORKERS

After making a general survey of the most important publications on the larval stages of trilobites, as mentioned in the introduction, the author has found that the following characteristics, changes, and modifications appear to have been accepted by most students of the group:

The eyes and palpebral lobes are supposed to have migrated from the ventral side, first forward to the margin and then backward over the cephalon to their adult position. In the protaspides of some forms, such as *Dalmanitina socialis* Barrande and *Proetus parviusculus* Hall, the eyes are located on the anterior margin, projecting slightly in an anterior direction. In others the eyes are not present at any stage.

The axial lobe of the cephalon, in later protaspid stages, has five segments, indicating the presence of as many paired appendages on the ventral side. In its simplest state it expands in front, forming the anterior margin of the cephalon, as in *Ptychoparia* and *Sao*. The axial lobe gradually becomes simpler and the segmentation may be entirely lost as the animal increases in size. The pleurae of the neck-segment are the only ones to be distinguished on the cephalon in some of the later forms of the protaspid period.

The free-cheeks are absent or very small in all forms during the protaspid period. As they bear the visual areas of the eyes, their appearance on the dorsal shield is practically simultaneous with that of these organs. It is, therefore, inferred that before the eyes have travelled over the margin the free-cheeks must be wholly ventral in position.

The growth of the pygidium, after it makes its first appearance, is very considerable throughout the protaspis period. At first it is less than one-third the length of the dorsal shield, but by the successive addition of segments, it soon becomes nearly one-half the length.

DISCUSSION

The characteristics and modifications of the larval stages of trilobites which have been generally accepted by most workers are exhibited only in part by the forms described and figured in this paper. The position of the eyes, palpebral lobes, free cheeks, and the anterior invagination differ in some respects from those set forth by earlier workers; the other characteristics are as would be expected from previous observations.

The eye-ridges, palpebral lobes, and free-cheeks (but no eyes) are present on the dorsal side of the shell and slightly posterior to the anterior margin in the youngest form of the protaspis, represented by Plate 47, figure 1, as well as in succeeding

forms in the protaspid period. This feature agrees very closely with that of the protaspides described by Strand (13) in his study of the ontogeny of *Olenus gibbosus* (Wahlenb.), in which he found well developed eye ridges and palpebral lobes in the youngest forms. Swinnerton (16) also pointed out the dorsal position of the eyes in the youngest larvae (described by Walcott) of the *Mesonacidae*, which he considers the most primitive of all trilobite larvae. The present writer has observed swellings on the anterior margins of some of the youngest forms in the protaspid stage that could easily have been mistaken for eyes. The dorsal position of the palpebral lobes behind the anterior margin on those same forms indicates, however, that the eyes are not actually marginal. The anterior invagination, as shown in Plate 47, figures 2 and 3, produces anterior swellings on each side of the axial lobe that could also be mistaken for anterior eyes.

To the writer it seems that the eyes appear later than the facial suture, palpebral lobes, and free-cheeks, and that instead of migrating over the margin from the ventral side, they are formed on the free-cheeks during some moult. This critical moult appears to come earlier in some trilobites than in others. It may be very early, as in the *Mesonacidae*, or late, as in *Sao* and *Ptychoparia*.

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PROTASPIDES OF TRILOBITES

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ABSTRACT

The discovery that the eyes of larval trilobites appear first on the dorsal side of the cephalon casts doubt on the customary interpretation that certain eye-less trilobites are specialized descendents of forms with functional eyes.

The work of Mr. C. G. Lalicker on the protaspides of the Middle Cambrian trilobites, as set forth in the preceding article, has been of great interest to me.

As one of Beecher's students, I have always accepted his dictum that the free cheeks and eyes of trilobites were first ventral, and that they gradually migrated over the margin to the dorsal side. Most protaspides are found in shales of exceedingly fine grain, and because of the small size of the specimens, it is impossible to get at the ventral surface. When, however, I found that the nodules weathered from the Middle Cambrian limestone of northeastern Alabama contained great numbers of protaspides, it occurred to me that some of them must have weathered out from the ventral side, making it possible to check Beecher's theory. Accordingly, I suggested to Miss Priscilla Webster, then a senior in Radcliffe College, that she study this collection with that idea in mind. Miss Webster and another Radcliffe student spent a considerable amount of time on the investigation, found specimens exposed from the ventral side, and developed them carefully, but the results were negative. No traces of ventral eyes were found, nor was there any evidence that the free cheeks were ventral.

Because of the negative nature of their results, nothing was published, and the material was held for further investigation. Miss Webster and her associate were handicapped because I had set them a definite problem, and indicated the probable solution. When Mr. Lalicker, who has had considerable experience as an investigator of microfossils, asked for a subject for investigation, I gave him the same material, but refrained from theories—"Here are some protaspides—see what you can make of them." He knew nothing about young trilobites; he merely recorded what he saw, uninfluenced by theories.

His most important discovery, substantiated by the specimens, is that facial sutures appear on the dorsal side of the cephalon of the trilobite before the visual surface of the eye can be detected, hence that

the eyes are "spontaneously generated" on the dorsal side of the cephalon, even in larvae of Medial Cambrian age. In other words, the eyes are not ventral in position in the earliest larvae, do not migrate over the antero-lateral margins, and are not necessary adjuncts of the free cheeks. This observation is of particular interest in connection with the recurrent question as to whether the trilobites grouped by Beecher as the Hypoparia are primitive or specialized. All students of the group admit that they present a curious combination of primitive and highly specialized characteristics. The chief question has been about the eyes. Beecher considered that the absence of compound eyes indicated a primitive condition. Such eyes, if present, must have been ventral. Later writers, almost unanimously, have thought that their blindness was secondary; that they were descendants of trilobites with functional visual organs. Note, for example, the ampycids, *Ampyx*, *Lonchodomas*, etc. Although the free cheeks are chiefly ventral, a portion of each appears on the dorsal surface, yet there is no trace of an eye. According to most modern writers, this indicates the complete loss of the primitive compound eye through adaptation of the adult to life in the deeper parts of the oceans. The true interpretation, as indicated by Lalicker's studies, would be the opposite: that, because of retention of primitive characteristics, eyes had never developed. Very likely there was an adaptational control. The adults as well as the larvae existed under aphotic or nearly aphotic conditions.

Mr. Lalicker's observations also tend to strengthen the evidence for the theory that the free cheeks are remnants of one of the anterior segments of the head. Their differentiation in even the youngest protaspides of these Middle Cambrian trilobites is rather surprising, but future study of larvae from Lower Cambrian may reveal a more primitive condition than is shown by these specimens.

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A REVISION OF THE PHACOPID TRILOBITES

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ABSTRACT

The family Phacopidae Hawle and Corda, 1847, of current usage, is made the superfamily Phacopidacea to receive the family Phacopidae, emend., and the new family Dalmanitidae. The family Phacopidae, as restricted, contains the subfamily Phacopinae Reed, 1905, and the new subfamilies Phacopidellinae, Acastinae, and Calmoninae; and includes also the new genera *Eophacops, Scotiella. Kloucekia, Ormathops, Acastoides, Probolops,* and *Schizostylus.* The family Dalmanitidae contains the subfamilies Dalmanitinae Reed, 1905, Pterygometopinae Reed, 1905, and the new subfamilies Synphorinae, Asteropyginae, and Zeliszkellinae; and includes also the new genera *Malvernia, Eudolatites, Anchiopsis, Trypaulites, Dalmanitoides, Kayserops, Greenops, Hadrorachus, Cryphaeoides, Achatella, Calliops, Eomonorachus,* amd *Zeliszkella.* The importance of differences in glabellar lobation in the taxonomy of the superfamily is emphasized throughout.

The revision of the phacopid trilobites here presented represents a summary of the results of two years work on the taxonomy of the group at the Museum of Comparative Zoology. The writer realizes that a portion of the results obtained may be based on data which are not entirely satisfactory, a circumstance traceable to the necessity for basing many important conclusions on published figures and descriptions. The limitations of this method of research are realized, and wherever possible, the writer has strengthened his study of the literature by examination of specimens in the collections of the Museum of Comparative Zoology.

The appended bibliography includes only a small portion of the total volume of publication relating to the phacopids, but, in the writer's opinion, includes all important publications concerning the taxonomy of the group.

The writer is happy to acknowledge his deep indebtedness to Professor Percy E. Raymond, of the Museum of Comparative Zoology, for his able guidance and assistance throughout the investigation; and to Professor Carey Croneis, of Walker Museum, for furnishing pertinent illustrative material.

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PREVIOUS WORK

The family Phacopidae, first named by Hawle and Corda (1847), has long been considered to form an homogeneous group. Indeed, the family as a whole was included in the single genus *Phacops* by Burmeister (1843, 1846). Barrande (1852, 1872) divided it into two genera, *Phacops* (genotype, *Calymene latifrons* Bronn), and *Dalmanites* (genotype, *Trilobus caudatus* Brünnich). Salter (1864) held that the family included only one genus, *Phacops*, which he divided into subgenera (*Phacops*

s.s., *Trimerocephalus*, *Acaste*, *Chasmops*, *Odontochile* or *Dalmania*, and *Cryphaeus*). Hall and Clarke (1888) used *Phacops* in a rather restricted sense, but assigned a very broad scope to *Dalmanites*, dividing it into several subgenera.

The first definite revision of the Phacopidae was attempted by Reed (1905), who divided it into three subfamilies (Phacopinae, Dalmanitinae, and Pterygometopinae), on the basis of structural features and evolutionary relationships, criteria which are today fundamental in the taxonomy of the family.

Wedekind (1911, 1914) and Kozlowski (1923) have also attempted to revise the family, but with indifferent success.

The austral members of the family have been discussed by Clarke (1890, 1913), Kozlowski (1923), and Reed (1925). Rudolph and Emma Richter (1926) have refined the criteria for the classification of the Phacopinae, and have more recently (1931) redefined *Dalmanites* and *Odontochile*. Their chief contribution has been a refinement of the taxonomic usage of subcephalic features and of the manner of eye obsolescence in the Phacopinae. Their principles appear to be sound, and the present writer has used them wherever possible.

Reed again summarized the status of the Phacopidae in 1927, and discussed the contributions made to the taxonomy of the family since 1905. For comparison with that proposed by the present writer, Reed's systematic scheme (1927, pp 351, 352) is repeated here.

Family PHACOPIDAE

Subfamily DALMANITINAE

Genus DALMANITES, s.s. (Hausmannia)

Subgenera Dalmanitina, s.s., Cryphaeus (Asteropyge), ? Comura, ? Metacanthus, Cryphina, Coronura, Odontocephalus, Corycephalus, Anchiopella, Probolium, Acastella, Proboloides, Synphoria.

Subfamily PHACOPINAE

Genus PHACOPS

Subgenera Phacops, s.s., Reedops, Phacopina, Phacopidella, s.s., Trimerocephalus, s.s., Dianops, Nephranops, Cryphops, Portlockia, ?Denckmannites, Bouleia, Dereimsia, Acaste, s.s. (Acastina nom. prop.), Calmonia, Pennaia.

Subfamily Pterygometopinae

Genus Pterygometopus

Subgenera Pterygometopus, s.s., Chasmops, Monorakos, ?Josephulus,

Incertae sedis.

Typhloniscus.

The present writer believes that although this rather simple taxonomic division of the family may have been effective previously, the demands of correct systematic usage will be fulfilled more completely by a somewhat different arrangement.

Study of various branches of the family indicates that it includes several divergent stocks. Well-defined glabellar lobation is primitive within the family, as shown by the morphology of the oldest species known: *Phacops nicholsoni* Salter and *Phacops llanvirnensis* Hicks, from the Skiddaw slates (Lower Ordovician) of the British Isles, and *Dalmanites atavus* Barrande from Stage D 1 gamma of the Bohemian Basin. These species have complete glabellar lobation, and convex, non-mucronate pygidia. In contrast, species in which

the glabellar lobation is obsolete may be considered as specialized.

The fundamental basis for classification is therefore an evolutionary one. Unfortunately, we know of no Cambrian Proparia which may be assigned to the Phacopidae. The writer believes that the Ordovician and younger Phacopidae represent divergent stocks, which evolved in radiate fashion from hypothetical generalized Cambrian ancestors.

The following systematic scheme is proposed, therefore, and all subsequent discussion is couched in terms of this arrangement.

SYSTEMATIC DESCRIPTIONS

Sub-Class TRILOBITA
Order PROPARIA
Superfamily PHACOPIDACEA Delo, n. superf.

Proparia with schizochroal eyes, large free cheeks, and 11 thoracic segments.

Family 1. PHACOPIDAE Hawle and Corda, 1847, emend. Delo

Phacopidacea with reduced or obsolete anterior glabellar furrows, compact body form, and in most, a small rounded pygidium.

Subfamily A. PHACOPINAE Reed, 1905

Phacopidae with two anterior pairs of glabellar furrows nearly or entirely obsolete, more or less swollen glabella, subcranial furrow, and in most, rounded genal angles. Eyes vary in size, position; may be entirely absent. (Figs. 1*a–e*.)

Occurrence: Silurian and Devonian.

Distribution: Eurasia, Australia, North and South America.

The following genera are here referred to the subfamily:

Phacops Emmrich, 1839. Typical Phacopinae. Subcranial furrow continuous, hinder edge sharp, the higher; marginal ridge narrow; cephalic doublure slightly convex. Silurian and Devonian; Europe, North and South America, Australia.

Reedops R. and E. Richter, 1925. Subcranial furrow absent in front; eyes small, well forward; otherwise like *Phacops*. Silurian of Europe; ?Lower Devonian of North America.

Eocryphops R. and E. Richter, 1931. Eyes small with "cryptophthalmus pattern" (see below). Genal angles with a semicircular indentation, not concealing the first thoracic segment when enrolled. Upper Devonian, Europe.

Cryphops R. and E. Richter, 1926. Eyes in anterior corners of cheeks; visual area with "cryptophthalmus pattern"; marginal ridge broad; subcranial furrow deep and broad; doublure short, concave. Upper Devonian, Europe.

Trimerocephalus McCoy, 1849. Eyes absent; marginal ridge wide, convex; subcranial furrow wide, deep; doublure short, flat. Upper Devonian, Europe.

Nephranops R. and E. Richter, 1926. Eyes small or absent; kidney-shaped when present; palpebral lobes always present; subcranial furrow broad, anterior edge overhanging; marginal ridge broad; doublure very short. Upper Devonian, Europe.

Dianops R. and E. Richter, 1923. Eyes absent; facial sutures procumbent along cephalic border; subcranial furrow broad, anterior edge the higher; doublure long and even. Upper Devonian, Europe.

Bouleia Kozlowski, 1923. Glabella very highly inflated; second and third lateral furrows distinct; row of pointed sub-marginal denticles, largest in front. Devonian, Bolivia.

Dereimsia Kozlowski, 1923. Glabella subspherical, without trace of first and second furrows; conspicuously tuberculate. Devonian, Bolivia.

Eophacops Delo, n. gen., described below.

The genus *Portlockia* McCoy, 1846, is considered invalid because of confusion regarding the identity of the genotype.

During an advanced stage in the obsolescence of the eyes, the facets become greatly reduced in number and proportionally larger. The visual area becomes elliptical, and the facial suture, instead of curving forward along the posterior margin of the visual area, curves backward. (See figs. 4, 5.) The Richters have called this pattern the "cryptophthalmustracht" because it occurs characteristically in *Cryphops cryptophthalmus* (Emmrich). It is also present in *Ormathops barroisi* Novak from Stage D 1 gamma of the Bohemian Basin, in *Denckmannites volborthi* and its allies of Silurian age, *Dienstina diensti* R. and E. Richter, *Eocryphops kayseri* (Hermann), and *Phacops pentops* Ivor Thomas from the Upper Devonian, and in many other species of the Phacopidae. The Richters have defined it as follows: "Sehfläche elliptische werdend, nach innen konvex begrentz, augendeckel sich einebnend." (1926, p. 132.)

Genus EOPHACOPS Delo, n. gen.

Figures 2, 3

Phacops WELLER, *1907*, and authors; *Phacops* (*Portlockia*) MCLEARN, *1918*, *1924*; FOERSTE, *1919*; TWENHOFEL, *1928*; COOPER, *1930*; REED, *1931*; *Phacops* (*Phacopidella*) REED, *1906*.

Genotype, *Phacops handwerki* Weller, 1907 (p. 271, pl. 24, figs. 6, 7).

Generic Diagnosis: Small Phacopinae with subcranial furrow present laterally, frontal lobe not overhanging anterior cephalic margin, eyes large, cephalic doublure concave.

Discussion: The genus includes small, rather primitive phacopids in which the frontal lobe curves gently downward to the anterior margin, and does not overhang as in *Phacops*, s.s. The dorsal furrows of the cephalon do not diverge markedly as in most of the later genera of the Phacopinae. The eyes are large, rising at least to the glabellar surface or slightly above it. The facial suture is discernible.

Occurrence: Silurian.

Distribution: North America, northwestern Europe.

Subfamily B. PHACOPIDELLINAE Delo, n. subf.

Phacopidae with two anterior pairs of glabellar furrows nearly or entirely obsolete; no subcranial furrow; eyes vary in size and position, may be entirely absent.

Occurrence: Silurian and Devonian.

Distribution: Europe, ?Australia.

The following genera are here referred to the subfamily:

Phacopidella Reed, 1905. Cephalic border entire; frontal lobe detached laterally; first and second lobes coalesced; third tripartite; eyes large; pygidium large, rounded. Silurian, Bohemian Basin.

Denckmannites Wedekind, 1914. Glabellar surface uniform; eyes small, with "cryptophthalmus pattern"; pygidium like *Phacopidella*. Silurian and Lower Devonian, Europe.

Dienstina R. and E. Richter, 1931. First and second furrows obsolescent; third lobe undivided; eyes in "cryptophthalmus pattern"; palpebral lobes triangular; pygidium short. Upper Devonian, Europe.

Ductina R. and E. Richter, 1931. Eyes and palpebral lobes absent; facial suture on the cephalic border. Upper Devonian, Europe.

Adastocephalum Mitchell, 1919. Glabella without lobes or furrows; dorsal furrows subparallel. Lower Devonian?, Australia. (This genus is only tentatively referred to the subfamily. Its validity is in doubt, in the writer's opinion, because of the poor preservation of the holotype. Only the cephalon of the genotypic species is known).

Subfamily C. ACASTINAE Delo, n. subf.

Small, compact Phacopidae in which the anterior glabellar furrows are lightly impressed, the third pair usually deeper; eyes in most species small; pygidium small, rounded; mucronate in some species.

Occurrence: Ordovician to Devonian.

Distribution: Europe, eastern North America, South America.

Discussion: The subfamily includes the generalized phacopids, some of which appear to have been the forerunners of the later Phacopinae and Calmoninae.

A certain generalized pattern is found in all members of the Acastinae, which appears to possess the potentialities necessary for the type of structure exemplified by the later, more specialized phacopids. The rather convex glabella with weakly impressed anterior furrows can be conceived as lending itself readily to expansion, and to obsolescence of the furrows.

The writer does not believe that the more specialized forms were derived directly from the older species of the Acastinae. It seems plausible to suppose, however, that the structure exhibited by *Dalmanites phillipsi* Barrande illustrates that of the hypothetical ancestors of the Phacopidae s.s. It is because of

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FIGS. 1*a–e*.—Diagrammatic sections along the axial line of several of the Phacopinae, to show the relative positions of the marginal ridge, the facial suture, and the subcranial furrow. The dotted line indicates the position of the suture. 1*a*, Typical Dalmanitidae; 1*b*, *Phacops*, s.s.; 1*c*, *Trimerocephalus;* 1*d*, *Nephranops;* 1*e*, *Dianops*. After R. and E. Richter (1926, p. 127, text-fig. 15). (p. 404)

2, 3—*Eophacops handwerki* (Weller) (*Phacops h.* W.). 2, Dorsal view of the cephalon; 3, lateral view. From photograph of holotype, Walker Mus., Univ. Chicago, 10,749. (p. 405)

4—*Cryphops cryptophthalmus* (Emmrich), enlarged view of right eye and portion of the cephalon showing the position of the eye and the "cryptophthalmus pattern" of the visual area. From R. and E. Richter (1926, pl. 9, fig. 56f). (p. 404)

5—*Eocryphops kayseri* (Hermann), enlarged view of the left eye, showing the "cryptophthalmus pattern." From R. and E. Richter (1931, p. 145, text-fig. 4). (p. 404)

6, 7—*Kloucekia phillipsi* (Barrande) (*Dalmanites p.* B.). 6, Cephalon; the facial sutures are drawn incorrectly, as they actually cut the cephalic margin much nearer the genal angles; 7, pygidium. From Barrande (1852, pl. 26, figs. 31, 32). (p. 408)

8, 9—*Acastoides henni* (R. Richter) (*Acaste h.* R.), cephalon and pygidium as figured by Richter (1916, pl. 27, fig. 1) (p. 408)

10*a–e*—*Ormathops* Delo, n. gen., variation in size and position of the eyes. 10*a*, *O. atavus* var. *macrophthalmus;* 10*b*, var. *transiens;* 10*c*, var. *intermedius;* 10*d*, var. *microphthalmus;* 10*e*, var. *barroisi*. From R. and E. Richter (1926, p. 129, text-fig. 16). (p. 408)

11—*Ormathops atavus* (Barrande) (*Dalmanites a.* B.), typical pygidium, from Barrande (1872, pl. 5, fig. 8). (p. 408)

12–14—*Scotiella logani* (Hall) (*Dalmania l.* H.). 12, 13, Hall's original figures (1860, p. 156, fig. 18). 14, Glabella of "*Dalmanitina*" *logani*, as figured by McLearn (1924, pl. 27, fig. 3). (p. 409)

15, 16—*Schizostylus brevicaudatus* (Kozlowski) (*Dalmanites b.* K.). 15, Cephalon of the holotype as figured by Kozlowski (1923, pl. 2, fig. 6). 16, Kozlowski's drawing of the extension of the suture to the tip of the anterior spine (1923, p. 29, text-fig. 2, pt. 3*a*) (p. 410)

17–19—*Probolops glabellirostris* (Kozlowski) (*Proboloides g.* K.). 17, The holotype. 18, Drawing of a plaster cast of the mould of the same; from Kozlowski (1923, pl. 2, figs. 9, 9*a*). 19, Drawing of a lateral view of the cephalon showing the anterior protrusion of the frontal lobe into a spine, with the facial suture beneath it; from Kozlowski (1923, p. 29, text-fig. 2, pt. 2*a*). (p. 410)

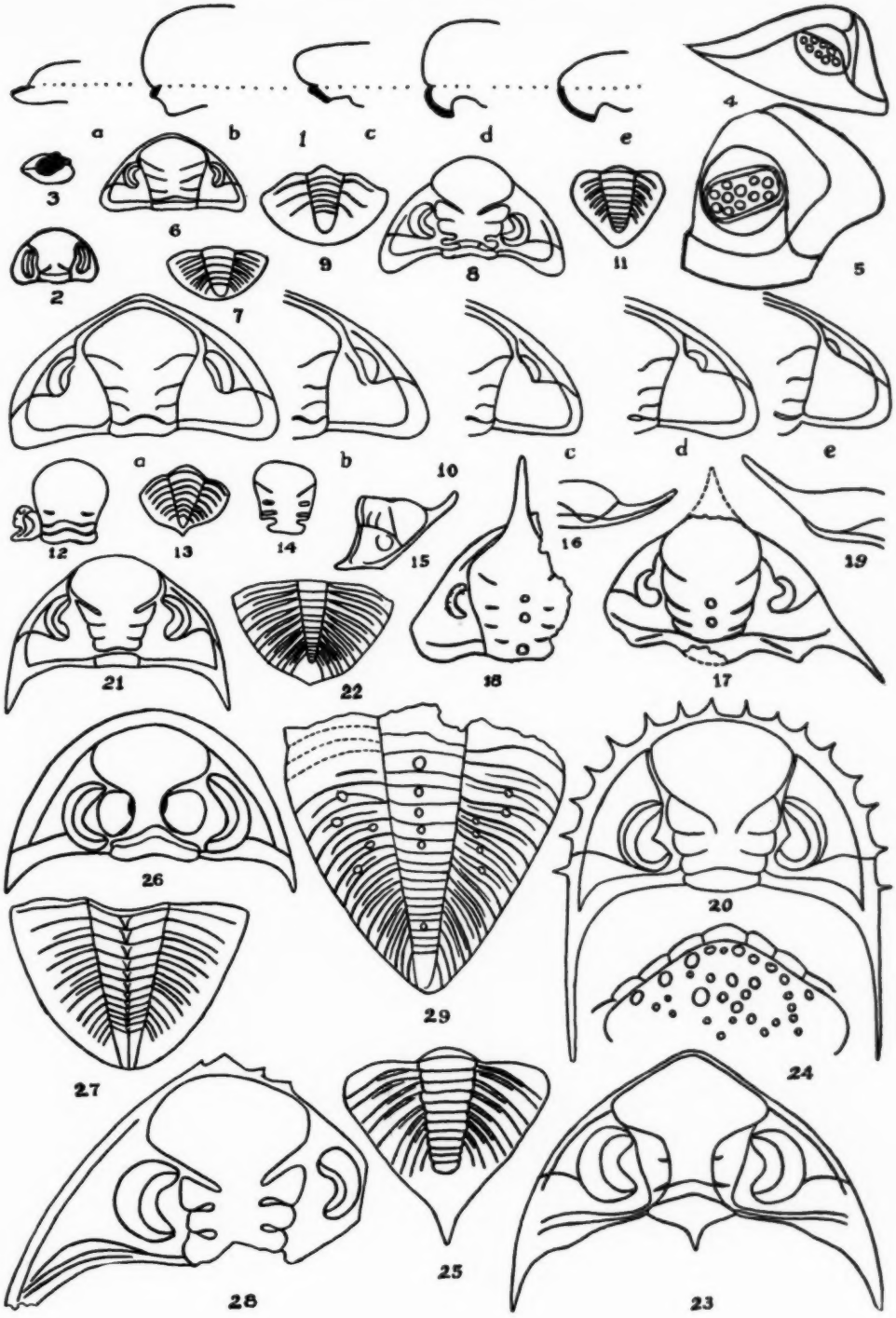
20—*Malvernia coronatus* (H. H. Thomas) (*Phacops* (*Dalmania*) *c.* T.), cephalon of the holotype as figured by Thomas (1900, pl. 35, fig. 4). (p. 411)

21, 22—*Eudolatites angelini* (Barrande) (*Dalmanites a.* B.), cephalon and pygidium; Barrande's original figure (1852, pl. 23, fig. 21, ×2). (p. 411)

23–25—*Anchiopsis anchiops* (Green) (*Dalmanites* (*Chasmops*) *a.* (G.) Hall and Clarke). 23, Small cephalon retaining the test; 24, enlargement of the anterior border; 25, a normal pygidium; from Hall and Clarke (1888, pl. 9, fig. 4; pl. 10, fig. 11, ×2; fig. 6). (p. 412)

26, 27—*Trypaulites calypso* (Hall) (*Dalmanites* (*Chasmops*) *c.* (H.) Hall and Clarke), cephalon and pygidium figured by Hall and Clarke (1888, pl. 11A, fig. 19, nat. size). (p. 412)

28, 29—*Dalmanitoides drevermanni* (Ivor Thomas) (*Dalmanites d.* T.). 28, 29, Cephalon and pygidium of holotype figured by Thomas (1905, pl. 11, figs. 1*a*, 3). (p. 413)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this apparent evolutionary relationship that he places the Acastinae within the family Phacopidae.

The following genera are here referred to the subfamily:

Acaste Goldfuss, 1843. Glabellar furrows converging toward a common point; third the deepest; pygidium small, rounded. Silurian; Europe, North America.

Acastella Reed, 1925. Like *Acaste* but with short genal spines and a mucronate pygidium. Silurian, Europe.

Phacopina Clarke, 1913. Anterior glabellar furrows indistinct; third deep; dorsal furrows sub-parallel; pygidium blunt. Lower Devonian, North and South America.

Acastoides Delo, n. gen., described below.

Kloucekia Delo, n. gen., described below.

Ormathops Delo, n. gen., described below.

Scotiella Delo, n. gen., described below.

Genus Acastoides Delo, n. gen.

Figures 8, 9

Genotype, *Acaste henni* R. Richter, 1909 (p. 95); 1916 (p. 252, pl. 25, figs. 13–16; pl. 27, figs. 1–3).

Generic Diagnosis: Acastinae with convex cephalon, well developed glabellar lobation, somewhat produced but non-spinose genal angles; first glabellar furrows well defined; second linear, horizontal, not fully meeting dorsal furrows; third very deep, wide, shallow in the mesial third, anteriorly convex; first and second pairs of glabellar lobes more or less coalescent, second slightly the smaller; third much narrower, anteriorly convex, distally depressed; nuchal furrow deep, wider mesially; nuchal lobe broad; eyes rather large. Pygidium moderately convex, rounded; pygorachis prominent, sparsely annulated (4 plus 1 in the genotype); pleural lobes smooth, only the anterior furrows perceptible.

Discussion: *Acastoides* differs from *Acaste* in the deeper anterior glabellar furrows, more or less detachment of the coalesced first and second lateral lobes from the remainder of the glabella, and much deeper third pair of lateral furrows.

Occurrence: Lower and ?Middle Devonian (Unter-Coblenzian).

Distribution: Rheinische Schiefergebirge.

Genus Kloucekia Delo, n. gen.

Figures 6, 7

Genotype, *Phacops phillipsi* Barrande, 1846 (p. 27). *Dalmanites phillipsi* Barrande, 1852 (p. 557, pl. 22, figs. 1, 2; pl. 26, figs. 31–36).

Generic Diagnosis: Acastinae with straight, almost parallel dorsal furrows; frontal border present only as a very narrow ridge; anterior furrows narrow, faintly impressed; the third pair wider, deeper; eyes large, attaining the glabellar level with a basal furrow, cheek area beneath them almost vertical; hinder branch of facial suture cutting lateral cephalic margin immediately adjacent to genal angle. Pygidium small, rounded, of moderate convexity, with wide smooth border; pygorachis narrow, with 3–5 annulations; pleural ribs furrowed, about 3 in number.

Occurrence: Ordovician (Stages D 2–D 4).

Distribution: Bohemian Basin.

Genus Ormathops Delo, n. gen.

Figures 10, 11

Genotype, *Dalmanites atavus* Barrande, 1872 (p. 28, pl. 5, figs. 8–14; pl. 15, figs. 8–14). *Dalmanitina atava atava* of later authors.

Generic Diagnosis: Acastinae with compact cephalon of moderate convexity, with narrow sloping border; first and second pairs of glabellar furrows narrow, lightly impressed; third deeper, widened submesially with a short, subordinate, backwardly directed branch, thus giving third glabellar lobe a tripartite appearance; Nuchal furrow wide; nuchal lobe broad and elevated; eyes of varying size, situated in anterior portion of the cheek, taking on the "cryptophthalmus pattern" with approaching obsolescence; genal spines absent. Pygidium non-mucronate, convex, more or less

pointed behind, with a broad border and few annulations.

Discussion: *Ormathops* is of great interest because it records the earliest known examples of eye-obsolescence in the Phacopidacea. The genus includes an homogeneous group of species, most of which were included formerly in *D. atavus* Barrande, and which have been differentiated subsequently through the efforts of Novak (1918), Perner (1918), and Kloucek (1916). The Richters (1926, p. 129) have referred briefly to this group in their discussion of the obsolescence of the eyes (idem., p. 16) and have indicated the intermediate position of *D. atava atava* within the group.

Occurrence: Lower Ordovician.

Distribution: Bohemian Basin (Stage D 1 gamma), British Isles (Upper Arenig).

Genus SCOTIELLA Delo, n. gen.

Figures 12–14

Dalmania HALL, *1860*, and early authors; *Dalmanites* BASSLER, *1915; Dalmanitina* MCLEARN, *1918, 1924.*

Genotype, *Dalmania logani* Hall, 1860 (p. 156, fig. 18). *Dalmanites logani* Bassler, 1915 (p. 385). *Dalmanitina logani* McLearn, 1924 (p. 167, pl. 27, figs. 3–6).

Generic Diagnosis: Acastinae with moderately convex cephalon; dorsal furrows almost parallel; anterior glabellar furrows faint to obsolescent, first directed obliquely backward, second horizontal, third wide and deep, interrupted mesially; eyes large; short genal spines may be present. Pygidium moderately convex, rounded, with short spine.

Discussion: The genus includes a series of species which have been referred variously to *Acaste*, *Dalmanites*, and *Dalmanitina*. But *Acaste* includes only those species in which the glabellar furrows are subequal and the pygidium nonmucronate. *Dalmanites* is typified by species with complete, deeply impressed glabellar segmentation, genal spines, and a large mucronate pygidium. *Dalmanitina* is confined to those species conforming to the pattern of *D. socialis* (Barrande). The present writer cannot agree, therefore, to McLearn's allocation of *Dalmania logani* to *Dalmanitina*.

The glabellar plan of *D. logani* agrees in some details with that of *Eophacops* (general glabellar plan, position of eyes), but the nature of the third glabellar furrows is different, and the pygidium is not phacopid.

Occurrence: Ordovician and Silurian.

Distribution: North America, northwestern Europe.

Subfamily D. CALMONINAE Delo, n. subf.

Phacopidae with low, compact glabella; narrow lateral furrows, anterior pairs tending toward obsolescence; pygidium small, compact in most instances.

Occurrence: Devonian.

Distribution: South Africa, South and North America, Falkland Islands.

Discussion: The Calmoninae include the genera placed by Clarke in the group Mesembria (1913, p. 116 et seq.). Mesembria cannot be used in the sense of a subfamily, however, as it has never been given generic rank. For this reason the name Calmoninae is proposed, following the typical genus *Calmonia* Clarke.

The following genera are here referred to the subfamily:

Calmonia Clarke, 1913. Facial sutures cutting lateral corners of the glabella; genal spines exsert; a rostral spine may be present; pygidium with six pairs of lateral spines, sometimes a median spine. Lower Devonian; South America, Falkland Islands, South Africa.

Pennaia Clarke, 1913. Genal and rostral spines absent; thororachis very broad; pygidium small, with three pairs of lateral spines, no median spine. Lower Devonian; South America, South Africa.

Anchiopella Reed, 1907. Genal spines small; nuchal lobe, thororachial and anterior pygorachial annulations spinose mesially; pygidium mucronate. Lower Devonian; South Africa, South America.

Proboloides Clarke, 1913. Rostral, supragenal, and pro-sutural spines may be present; thoracic pleurae distally spinose; pygidium small, rounded. Lower Devonian, South America.

Typhloniscus Salter, 1856. Eyes absent; cephalon coarsely tuberculate; pygidium small, rounded. Lower Devonian, South Africa.

Probolops Delo, n. gen., described below.

Schizostylus Delo, n. gen., described below.

Genus PROBOLOPS Delo, n. gen.

Figures 17–19

Genotype, *Proboloides glabellirostris* Kozlowski, 1923 (p. 52, pl. 2, figs. 9, 9*a*; text-fig. 2, pts. 2*a*, *b*, p. 29). The genotypic species is based on a single cephalon.

Generic Diagnosis: Calmoninae with frontal lobe of glabella prolonged into a spine, beneath base of which facial sutures border glabella; genal spines are present; posterior margin of cephalon bears a sharp angulation or rudimentary spine on either side, midway between dorsal furrow and genal angle; posterior glabellar furrows somewhat more reduced than in *Proboloides*, particularly nuchal furrow; otherwise superficially much like the latter genus.

Discussion: Although *Proboloides* and *Probolops* are superficially much alike, there are several striking differences. The frontal spines are not homologous, as that of *Proboloides* is a prolongation of the rostrum. In *Probolops* the third pair of glabellar lobes are about one-half as long as the second; in *Proboloides* they are about the same length.

Occurrence: Lower Devonian.

Distribution: Near Padilla, Bolivia.

Genus SCHIZOSTYLUS Delo, n. gen.

Figures 15, 16

Genotype, *Dalmanites brevicaudatus* Kozlowski, 1923 (p. 39, pl. 2, figs. 6–8; text-fig. 2, pt. 3*a*, p. 29). Figure 16 illustrates the holotype.

Generic Diagnosis: Acastinae? with cephalon moderately convex transversely; dorsal furrows subparallel; glabellar lobation well-marked; eyes small, extending from first to second furrow; upwardly inclined anterior spine present; facial sutures split it laterally so that ventral concave half is a continuation of doublure, upper convex half a prolongation of the cephalic border; sutures also cross antero-lateral corners of frontal lobe; each thoracic segment bearing a short spine. Pygidium very small, rounded; pygorachis equals one-third the total length, composed of 5 to 6 annulations, only first 3 distinct; 3 to 4 pleural ribs.

Discussion: The genus presents an interesting assemblage of features which normally occur in widely separated genera. There is no other genus in the Phacopidacea which bears an anterior spine of this type, the outstanding generic characteristic.

Occurrence: Lower Devonian.

Distribution: Letanias, Bolivia.

Family 2. DALMANITIDAE Delo, n. fam.

Phacopidacea with flattened body form, well defined glabellar lobation, large cephalon and pygidium, and in most, large eyes.

Subfamily A. DALMANITINAE Reed, 1905.

Dalmanitidae with unmodified glabellar lobation, large cephalon with genal spines, and large depressed pygidium, in most species mucronate.

Occurrence: Ordovician to Devonian.

Distribution: Eurasia, North and South America, Australia.

Discussion: The subfamily includes the orthodox stock of dalmanitids, from which sprang apparently the aberrant and often highly ornamented forms embraced by other subfamilies of the Dalmanitidae.

The following genera are here referred to the Dalmanitinae:

Dalmanites Barrande, 1852. Hypostoma elongate, non-denticulate; genal spines pres-

ent; 11 to 16 pygorachial annulations. Silurian; Europe, North America, ?Australia.

Dalmantina Reed, 1905. Frontal lobe not detached; frontal border absent; hypostoma short, rounded or subquadrate; less than 11 pygorachial annulations. Ordovician, Europe.

Odontochile Hawle and Corda, 1847. Genal spines present; hypostoma elongate, denticulate; 16 to 22 pygorachial annulations. Lower Devonian; Europe, North and South America.

Malvernia Delo, n. gen., described below.

Eudolatites Delo, n. gen., described below.

The subgenus *Hausmannia* Hall and Clarke, 1888, is considered as invalid because preoccupied by Odontochile.

Genus MALVERNIA Delo, n. gen.
Figure 20

Genotype, *Phacops* (*Dalmania*) *coronatus* H. H. Thomas, 1900 (p. 616, pl. 35, figs. 1–4).

Generic Diagnosis: Small Dalmanitinae with continuous cephalic border, the margin of which is produced into rather widely spaced, short, acute points; posterior thoracic segments somewhat produced, acuminate, curved backward distally. Pygidium small for the subfamily, mucronate.

Discussion: The specimens upon which the genotype was based are small, averaging three-eights to five-eights inches in length, but apparently mature. The species cannot be assigned to *Dalmanites*, s.s., because of the marginal spines on the cephalon, but in other details is very similar to the latter genus. The ornamentation of the cephalic margin is in some ways similar to that of *Corycephalus* Hall and Clarke (Synphorinae), but in the latter the marginal denticles are set much closer together, and the glabellar lobation is synphorinid.

Occurrence: Upper Middle Silurian (Wenlock shale).

Distribution: Malvern, England.

Genus EUDOLATITES Delo, n. gen.
Figures 21, 22

Genotype, *Dalmanites angelini* Barrande, 1852 (p. 918, pl. 23, figs. 21–27); 1872 (p. 27, pl. 9, fig. 1).

Generic Diagnosis: Dalmanitinae without frontal border; frontal lobe more or less detached, protuberant; second and third glabellar furrows straight, rather narrow; eyes varying somewhat in position, usually large; genal spines may be present. Pygidium broadly subtriangular, border indistinct; pygorachis rather narrow, consisting of less than 15 annulations.

Discussion: The species comprising *Eudolatites* apparently represent an offshoot from the principal stem of dalmanitid evolution. Thus the cephalon of *D. angelini* except for the straight second and third glabellar furrows is very similar to that of *D. socialis*, but the pygidium has the number of annulations typical of *Dalmanites* (*Dalmanitina* less than 11).

Occurrence: Upper Ordovician and Silurian.

Distribution: Europe.

Subfamily B. SYNPHORINAE Delo, n. subf.

Dalmanitidae with more or less complete distal fusion and elevation of first two pairs of glabellar lobes, and reduction of the second and third lateral furrows to sub-mesial pits; cephalon and pygidium may be modified by spines, denticles, or crenulations.

Occurrence: Devonian.

Distribution: North and South America, Europe, ?South Africa.

Discussion: The type of glabellar structure embraced by the Synphorinae was first noted by Clarke (1894, p. 733). The taxonomic rank of the term *Synphoria* then suggested for this group was not then stated. Clarke later defined *Synphoria* (1900, p. 15) as a subgenus of *Dalmanites*, and noted its connection with the other related groups defined as subgenera of *Dalmanites* by Hall and Clarke (1888). The acme of lobal coalescence and elevation among these is illustrated by the Devonian species allocated to *Dalmanites* (*Chasmops*) by Hall and Clarke (1888). However, *Chasmops* is a genus in the sub-family Pterygometop-

inae, and the Devonian species are in no way related to it.

The following genera are here included in the Synphorinae:

Synphoria Clarke, 1900. Cephalic margin smooth, crenulated, or with a simple median protrusion; pygorachial annulations usually about 15 in number. Lower Devonian, North and South America.

Probolium Oehlert, 1889. Carapace usually tuberculate; a rostral spine, which may be bifid or trifid, and a caudal spine present. Lower Devonian; Europe, North America.

Corycephalus Hall and Clarke, 1888. Cephalic margin with a row of separate denticles or short spines; genal spines present. Lower and Lower Middle Devonian, North America.

Odontocephalus Conrad, 1840. Cephalic border with distally coalesced spines in front of the glabella; pygidium with a crescent-shaped terminus of two spines. Lower Middle Devonian, North America.

Coronura Hall and Clarke, 1888. Pygidium with numerous lateral spines and a crescent-shaped, spinose terminus. Lower Middle Devonian, North America.

Malladaia Oehlert, 1896. Third lateral lobes greatly reduced; lateral margin of pygidium crenulated. Lower Devonian, Spain.

Anchiopsis Delo, n. gen., described below.

Trypaulites Delo, n. gen., described below.

Dalmanitoides Delo, n. gen., described below.

Genus Anchiopsis Delo, n. gen.

Figures 23–25

Calymene Green, *1832*, and early authors; *Phacops* Burmeister, *1843; Dalmania* Hall, *1861; Dalmanites* (*Chasmops*) Hall and Clarke, *1888;* Ohern and Maynard, *1913; Dalmanites* Goldring, *1933.*

Genotype, *Calymene anchiops* Green, 1832 (p. 35, cast no. 7). *Dalmanites* (*Chasmops*) *anchiops* Hall and Clarke, 1888 (p. 59, pl. 9, figs. 1–6, 10, 12, 13; pl. 10, figs. 1–4).

Generic Diagnosis: Synphorinae with cephalon short and wide; glabellar lobes confluent and highly elevated distally; second and third pairs of lateral furrows represented by rounded pits separated by rounded depressed median ridge; dorsal furrows continuous, but less deeply impressed than first lateral pair, which tend to join the sub-mesial pits and divide posterior portion of glabella into three linear ridges; nuchal and genal spines may be present. Pygidium triangular, with short, triangular upturned spine; pygorachis short, bluntly terminated, consisting of less than 15 annulations; pleural ribs show only faint distal furrowing, absent on casts.

Discussion: Hall and Clarke erroneously assigned *D. anchiops* to *Chasmops* because of the marked lobal coalescence, but *Chasmops*, by definition, applies only to species in which the first pair of glabellar lobes are greatly enlarged and the second pair greatly reduced (type: *Calymene odini* Eichwald). This is by no means the case in *D. anchiops*.

Occurrence: Lower and Middle Devonian.

Distribution: North America.

Genus Trypaulites Delo, n. gen.

Figures 26, 27

Dalmania and *Dalmanites* Hall, *1861* et. seq.; *Dalmanites* (*Chasmops*) Hall and Clarke, *1888; Dalmanites* (*Odontochile*) Goldring, *1931.*

Genotype, *Dalmania calypso* Hall, 1861 (p. 61). *Dalmanites* (*Chasmops*) *calypso* Hall and Clarke, 1888 (p. 64, pl. 11A, figs. 19–22). *Dalmanites* (*Odontochile*) *calypso* Goldring, 1931 (p. 386).

Generic Diagnosis: Synphorinae with coalescence of all three pairs of glabellar lobes advanced; frontal lobe small, transversely elliptical; median portion of glabella between first and second lobes depressed; second and third glabellar furrows reduced to shallow pits; dorsal furrows much reduced and elevated opposite eyes; eyes large, with elevated palpebral lobes; short genal spines, broad uninterrupted cephalic border.

Pygidium rounded behind, moderately convex, with well-defined border; pygorachis of less than 15 annulations, con-

tinuing to posterior margin; pleural ribs flat, broad, indistinctly furrowed.

Discussion: Although the degree of fusion of the lateral lobes reaches about the same stage in *Trypaulites* as in *Anchiopsis*, there is no possibility of confusing members of the two genera. The frontal lobe in *Anchiopsis* is more or less rhomboidal, that of *Trypaulites* more nearly circular. The fused lateral lobes of the former are much more highly elevated, the cephalon increases in elevation posteriorly and is much more convex.

The pygidial features of *Trypaulites* are found in no other genus of the Dalmanitidae.

Occurrence: Lower Middle Devonian.

Distribution: North America.

Genus DALMANITOIDES Delo, n. gen.

Figures 28, 29

Genotype, *Dalmanites drevermanni* Ivor Thomas, 1906 (p. 247, pl. 11, figs. 1, a, 2, a, 3).

Generic Diagnosis: Synphorinae with anterior margin showing a short median projection and two pairs of lateral denticles, the second of which is located about two-thirds the distance from median spine to antero-lateral corner of glabella; glabella pustulose; genal spines present. Each thororachial annulation with large median and two smaller tubercles; each pleuron with two or three spinose tubercles. Pygidium rather narrowly triangular; pygorachis narrow, with 18 annulations, several of which bear a pair of spinose tubercles; end of pygorachis distinctly swollen; pleural lobes have 14 pairs of ribs, ornamented with scattered tubercles.

Discussion: In general cephalic plan, frontal ornamentation, and tuberculation, *Dalmanitoides* is typical of the Lower Devonian synphorinids. It is analogous to the element in the boreal fauna which gave rise to such forms as *Corycephalus* Hall and Clarke, and is somewhat similar in ornamentation to *Dalmanites pleuroptyx* (Green) and *Dalmanites pratteni* Roy.

Occurrence: Upper part of the Lower Devonian.

Distribution: West of Jachal Valley, Argentina.

Subfamily C. ASTEROPYGINAE Delo, n. subf.

Dalmanitidae with relatively unmodified glabellar lobation and genal spines; pleural extremities progressively produced or spinose posteriorly. Pygidium with five pairs of marginal spines or lappets, which are continuations of the anterior branch of the pleural ribs; terminal spine or process may be present.

Occurrence: Devonian.

Distribution: Europe, Asia Minor, North America, South America and Falkland Islands, South Africa.

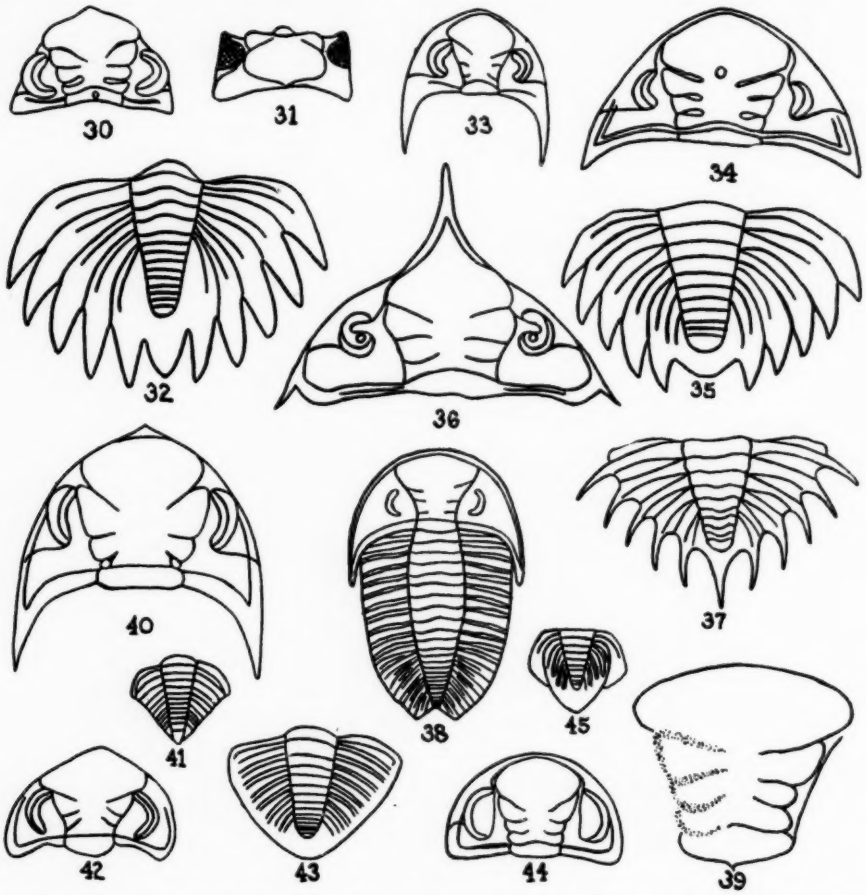
Discussion: The group of dalmanitid forms comprising the subfamily have long been referred to the genus *Cryphaeus* Green, 1837, despite its preoccupation by *Cryphaeus* Klug, 1833 (Coleoptera). They all possess in common a multi-spinose or lappeted pygidium, a feature so conspicuous that other more fundamental taxonomic features have been ignored, and much systematic confusion introduced. R. Richter (1909) has adequately elucidated the importance of glabellar features within the group, and assigned pygidial features to a secondary role in classification. The writer is in thorough agreement with this viewpoint.

The following genera are here referred to the subfamily:

Asteropyge Hawle and Corda, 1847. Glabella more or less depressed; nuchal furrow shallow mesially; pygorachis with 12 or more annulations, first 5 distinct; a sixth pair of pleural ribs sometimes present; no terminal spine. Upper Lower to lower Upper Devonian; Europe, Asia Minor.

Metacanthus Hawle and Corda, 1847. Glabella not depressed; nuchal lobe narrow; thoracic pleurae spinose distally; pygorachis with 5 distinct and 2 to 5 indistinct annulations; a sixth pair of pleural ribs never present; terminal spine always present. Middle and Upper Devonian; Europe, Asia Minor.

Comura R. and E. Richter, 1926. Cephalon like *Metacanthus;* lateral and terminal pygidial spines very long, with a prominent tu-



FIGS. 30, 31—*Kayserops kochi* (Kayser) (*Cryphaeus k.* K.), cephalon as figured by R. Richter (1916, pl. 26, figs. 2*a*, *b*). (p. 415)

32, 33—*Greenops boothi* (Green) (*Dalmanites* (*Cryphaeus*) *b.* (G.) Hall and Clarke). 32, Large pygidium with typical spines; 33, normal cephalon. From Hall and Clarke (1888, pl. 16, fig. 3; pl. 16A, fig. 7, nat. size). (p. 415)

34, 35—*Hadrorachus australis* (Clarke) (*Cryphaeus a.* C.). 34, Normal cephalon; 35, normal pygidium. From Clarke (1913, pl. 3, figs. 9, 13) (p. 415)

36, 37—*Cryphaeoides rostratus* (Kozlowski) (*Cryphaeus r.* K.) 36, Composite drawing of a typical cephalon of the species, from Kozlowski (1923, pl. 5, figs. 1, 3, 6); 37, normal pygidium (same, pl. 5, fig. 9). (p. 416)

38—*Achatella achates* (Billings) (*Dalmanites a.* B.), the original figure of the holotype; end of pygidium broken; after Billings (1860, p. 63, text-fig. 9). (p. 416)

39—*Achatella achates* (Billings) (*Pterygometopus a.* (B.) Foerste), glabella of a specimen figured by Clarke (1894, p. 727, fig. 44), after being cleaned and redrawn by Ruedemann; from Foerste (1919, pl. 19, fig. 8). (p. 416)

40, 41—*Eomonorachus intermedius* (Walcott) (*Pterygometopus i.* (W.) Clarke). 40, Cephalon, from Cooper (1930, text-fig. 7*d*); 41, pygidium, from Clarke, (1894, p. 728, fig. 47, ×2). (p. 417)

42, 43—*Calliops callicephalus* (Hall) (*Pterygometopus c.* (H.) Clarke), holotype. 42, Cephalon; 43, pygidium. Hall's specimen, after Clarke (1894, p. 731, fig. 51; fig. 52, ×2). (p. 417)

44, 45—*Zeliskella deshayesi* (Barrande) (*Dalmanites d.* B.), cephalon and pygidium of this unusual species, after Barrande (1852, pl. 27, figs. 10, 11). (p. 418)

bercle at the base of each lateral spine. Devonian, Europe.

Cryphina Oehlert, 1889. Pygidium with 7 pairs of very short, recurved lateral spines; no terminal spine; cephalon unknown. Middle Devonian, France.

Kayserops Delo, n. gen., described below.

Greenops Delo, n. gen., described below.

Hadrorachus Delo, n. gen., described below.

Cryphaeoides Delo, n. gen., described below.

The genus *Cryphaeus* Green, 1837, is preoccupied by *Cryphaeus* Klug, 1833, (Coleoptera).

Genus KAYSEROPS Delo, n. gen.

Figures 30, 31

Cryphaeus KAYSER, *1883* (part), and later authors. *Asteropyge* (*Metacanthus*) R. and E. RICHTER, *1926* (part).

Genotype, *Cryphaeus kochi* Kayser, 1883 (p. 37, pl. 3, fig. 6). *Cryphaeus lethaeae* Kayser, 1889 (p. 86, pl. 23, figs. 7–9). *Cryphaeus kochi* R. Richter, 1909 (pp. 69–74); 1916 (p. 250, pl. 25, figs. 6–9; pl. 26, figs. 1–6).

Generic Diagnosis: Asteropyginae with cephalon highly convex, without anterior border; first and second glabellar lobes swollen, rising slightly above mesial portion and frontal lobe; third lateral lobes short, narrow, greatly depressed; nuchal lobe prominent, anteriorly convex; eyes very large, rising to glabellar level. Pygidial features as in *Metacanthus*.

Discussion: Kayser first described *C. kochi* from the Orthocerasschiefer (Middle Devonian) of Germany. The holotype is a rather complete, but crushed cast. His figure shows the highly swollen glabellar lobes and rounded pygidium with short, broad spines. A narrow median spine is present. Richter has described the species in detail (1909, pp. 69–74) but did not give a figure of it. He placed it in the same series with *Metacanthus stellifer* (Burmeister).

The present writer believes that *M. stellifer* and *C. kochi* cannot be considered as congeneric because of the fundamental difference in the glabellar lobation. He knows of no other species which can be assigned to *Kayserops*.

Occurrence: Middle Devonian (Upper Coblenzian).

Distribution: Rheinische Schiefergebirge.

Genus GREENOPS Delo, n. gen.

Figures 32, 33

Genotype, *Cryphaeus boothi* Green, 1837 (p. 217, 2 woodcuts). *Dalmanites* (*Cryphaeus*) *boothi* Hall and Clarke, 1888 (p. 42, pl. 16, figs. 1–4; pl. 16A, figs. 3–8).

Generic Diagnosis: Asteropyginae with moderately convex cephalon, widely diverging dorsal furrows; glabella gently arched both transversely and longitudinally; frontal lobe transverse; first and second lateral lobes coalesced distally but not swollen; second lateral furrows reduced to rounded pits (elongate transversely on casts); third lateral lobes much reduced; third furrows short, deep, not entering dorsal furrows at their level (much deeper on casts); eyes of moderate size, visual area low, elevated to or slightly above glabellar level; genal spines large, compressed. Pygidium much like that of *Metacanthus* in outline and convexity; pleural ribs wide, flat, with narrow but distinct interpleural furrows.

Discussion: The North American species show very little variation, and specific differentiation is based largely on pygidial features. The most complete discussion is that of Hall and Clarke (1888, pp. 41–48).

Occurrence: Middle and Lower Upper Devonian.

Distribution: North America.

Genus HADRORACHUS Delo, n. gen.

Figures 34, 35

Genotype, *Cryphaeus australis* Clarke, 1913 (p. 108a, pl. 3, figs. 7–14; pl. 4, figs. 1–5).

Generic Diagnosis: Asteropyginae with cephalon moderately convex; well defined lobation; small eyes set well forward, not elevated; genal spines short; nuchal furrow wide; nuchal lobe narrow. Thoro-rachis broad, about as wide as pleural lobes; pleural extremities moder-

ately produced, pointed, but not spinose. Pygidium gently convex; pygorachis broad, blunt; of 5 distinct and 4 to 6 indistinct annulations; lateral spines short, acute, or blunt and rounded; median process very short.

Discussion: *Hadrorachus* differs in general from all other genera of the Asteropyginae in the very broad axial lobe, small eyes located well forward, deep and broad nuchal furrow, and short genal spines.

Occurrence: Devonian.

Distribution: Brazil, Bolivia, Falkland Islands, South Africa.

Genus CRYPHAEOIDES Delo, n. gen.

Figures 36, 37

Genotype, *Cryphaeus rostratus* Kozlowski, 1923 (p. 44, pl. 5, figs. 1–10). The specimen illustrated by figure 2 is designated as the genotype in the absence of a definite statement by the original author.

Generic Diagnosis: Asteropyginae with elliptical glabella; greatest width measured across the first pair of lateral lobes, which are much wider than the second and third pairs; a true rostral spine present, about as long as frontal lobe; eyes rather small; the eye-axis forming definite angle with the body axis; sharp angulation or rudimentary exsert spine present at the widest portion of cephalon, somewhat in front of genal angle, but well behind corner of the free cheek; nuchal lobe bears short vertical spine. Each thoracic segment with short rachial spine; these reduced on the pygidium. Pygidium broadly triangular, depressed-convex, bearing five pairs of slender, curved marginal spines and slender median one.

Discussion: This is the only austral representative of the Asteropyginae which possesses slender pygidial spines. The rostral spine and swollen anterior glabellar lobes are important differential features.

Occurrence: Devonian.

Distribution: Patacamaya and other localities, Bolivia.

Subfamily D. PTERYGOMETOPINAE Reed, 1905.

Small Dalmanitidae with tendency toward hyperthropy of first pair of glabellar lobes, or hyperthropy and fusion of first and second pairs, reduction of third. Pygidium of moderate size, nonmucronate, in most species rather convex.

Occurrence: Ordovician.

Distribution: Northwestern Europe; ?Burma; North America; Siberia.

The following genera are here referred to the subfamily:

Pterygometopus Schmidt, 1881. Frontal lobe very alate, cut laterally by the facial suture; lateral lobes rounded, progressively smaller backward; eyes large; pygidium more or less elongate. Ordovician; Northern Europe, ?Burma.

Chasmops McCoy, 1849. First lateral lobes greatly enlarged, triangular; second very small; eyes small, cone-shaped; pygidium strongly convex. Ordovician; Northern Europe, northeastern North America.

Monorakos Schmidt, 1886. First and second lateral lobes fused and enlarged; second lateral furrows reduced to sub-mesial pits; eyes small. Ordovician, Siberia.

Calyptaulax Cooper, 1930. First and second lateral lobes coalesced; second lateral furrows very shallow, not reaching the dorsal furrow; eyes very long. Ordovician; North America, Greenland, British Isles.

Achatella Delo, n. gen., described below.

Eomonorachus Delo, n. gen., described below.

Calliops Delo, n. gen., described below.

The genus *Pterygometopidella* Wedekind, 1911, is considered to be a synonym of *Portlockia* McCoy.

Genus ACHATELLA Delo, n. gen.

Figures 38, 39

Genotype, *Dalmanites achates* Billings, 1860 (p. 63, fig. 9). *Pterygometopus achates* Foerste, 1919 (p. 397, pl. 19, figs. 8, 18a).

Generic Diagnosis: Pterygometopinae with broadly rounded cephalic margin,

very alate frontal lobe, unreduced third lateral lobes, broad and elevated nuchal lobe, highly elevated, cone-shaped eyes set near the center of the cheeks, and genal spines. Pygidium subtriangular, indistinctly bordered, with wide furrowed pleural ribs and narrow inter-pleural furrows. Convexity of entire animal is much less than in *Pterygometopus*, s. s.

Discussion: *Achatella* differs from *Dalmanites*, s. s., in the alate frontal lobe which is not detached from the remainder of the glabella, expanded nuchal lobe, and indistinctly bordered pygidium. It differs from *Dalmanitina*, s. s., in the nature of the frontal lobe, presence of a frontal cephalic border, cone-shaped eyes, elevated and broad nuchal lobe, and wide pygidial ribs. *Pterygometopus* is more closely related, but *Achatella* differs in more rounded cephalic outline, lesser convexity, relative size of the second and third lateral lobes, and nature of the nuchal lobe.

Occurrence: Middle and Upper Ordovician.

Distribution: North America, British Isles.

Genus EOMONORACHUS Delo, n. gen.

Figures 40, 41

Genotype, *Dalmanites intermedius* Walcott, 1877 (p. 16); 1879 (p. 69). *Pterygometopus intermedius* Clarke, 1894 (p. 727, 728, text-figs. 45–47).

Generic Diagnosis: Pterygometopinae with frontal lobe not conspicuously alate; first and second lateral lobes more or less coalesced, offset from median portion of glabella by axial depressions; second lateral furrows complete, narrow, shallow, deeper proximally; third lobes reduced to pair of distal tubercles and low median ridge. Pygidium sharply triangular, strongly convex, indistinctly bordered; narrow pygorachis extending to its extremity.

Discussion: *Eomonorachus* marks a stage in the phylogenetic sequence within the Pterygometopinae between *Pterygometopus*, s.s., and *Calyptaulax* Cooper. *Pterygometopus* has the second lateral furrows deeper distally, meeting the dorsal furrows at their level. In *Eomonorachus* the second lateral furrows are complete but do not reach the dorsal furrows at their level, and are deepest at their mesial ends. A further change is noted in *Calyptaulax* in which the furrows are incomplete. The acme is reached in *Monorakos* Schmidt, in which the furrows are reduced to pits and the first and second lobes greatly enlarged.

Occurrence: Middle Ordovician.

Distribution: North America.

Genus CALLIOPS Delo, n. gen.

Figures 42, 43

Genotype, *Phacops callicephalus* Hall, 1847 (p. 247, pl. 65, figs. 3a–i). *Dalmania callicephala* Hall, 1859 (p. 73). *Pterygometopus callicephalus* Clarke, 1894 (p. 731, figs. 51, 52) and later authors.

Generic Diagnosis: Petrygometopinae with frontal lobe not conspicuously alate, sharply bounded, only slightly wider than large first glabellar lobes, which are distinctly triangular; second glabellar furrows narrower, shallower than first and third; eyes large, with conspicuously swollen palpebral lobes reaching backward to posterior marginal furrow; nuchal lobe prominent. Pygidium convex never mucronate, much as in *Pterygometopus*, s.s.

Discussion: The genus differs primarily from *Pterygometopus* s.s. as typified by *P. sclerops* (Dalman) in the less alate frontal lobe which slopes abruptly to the cephalic border. In *P. sclerops* the lateral lobes are more or less elliptical, grading downward in size backward, the first lobe much narrower than the frontal. In *Calliops*, by contrast, the first lateral lobes are very large, definitely triangular, and only slightly shorter than the frontal lobe. The first lateral furrows are directed obliquely backward, the second obliquely forward, and the third almost parallel to the second. The abrupt reduction in the size of the second and third lateral lobes gives the glabella a distinctly club-shaped appearance.

Calliops differs from *Eomonorachus* in the much smaller size of the second lateral lobes and the mesially arched glabella. It differs from *Calyptaulax* in the smaller size of the second lateral lobes and the complete second lateral furrows which reach the dorsal furrows.

Occurrence: Ordovician.

Distribution: North America.

Subfamily ZELISZKELLINAE Delo, n. subf.

Dalmanitidae with unmodified glabellar lobation and smooth continuous cephalic border; genal angles rounded; eyes very large, with conspicuous, smoothly sloping palpebral lobes. Pygidium small, subtriangular; pleural ribs and posterior thoracic pleurae bent backward parallel with rachis.

Occurrence: Ordovician.

Distribution: Bohemian Basin.

Discussion: The subfamily contains only the genus *Zeliszkella*, and its taxonomic position is not entirely clear. It is here allocated to the Dalmanitidae on the basis of glabellar features. The nature of the pygidium is considered as of secondary taxonomic importance.

Genus ZELISZKELLA Delo, n. gen.

Figures 44, 45

Genotype, *Phacops deshayesi* Barrande 1846 (p. 7). *Dalmanites deshayesi* Barrande, 1852 (p. 550, pl. 26, figs. 41-43; pl. 27, figs. 10, 11), and authors.

Generic Diagnosis: Cephalon moderately convex, with continuous border, rounded genal angles; first lateral furrows directed obliquely backward, sigmoid; second and third directed slightly toward each other; eyes large, their axes diverging outward somewhat; nuchal lobe wide, elevated. Thoracic pleurae bent downward abruptly distally; posterior pleurae bent progressively backward, the eleventh circumscribing anterior portion of the pygidium. Pygidium small, of few segments, more or less pointed behind but not spinose; pygorachis short; pleural ribs furrowed, bent backward parallel to pygorachis; posterior portion of pygidium a wide produced border which may be mesially carinate.

Occurrence: Ordovician.

Distribution: Bohemian Basin.

CONCLUSION

The proposed systematic scheme may be summarized as follows:

Superfamily PHACOPIDACEA Delo, n. superf.

Family 1. PHACOPIDAE Hawle and Corda, emend. Delo

Subfamily A. PHACOPINAE Reed

Genera *Phacops*, Emmrich, s.s., *Reedops* R. and E. Richter, *Trimerocephalus* McCoy, *Eocryphops* R. and E. Richter, *Cryphops* R. and E. Richter, *Nephranops* R. and E. Richter, *Dianops* R. and E. Richter, *Bouleia* Kozlowski, *Dereimsia* Kozlowski, *Eophacops* Delo, n. gen.

Subfamily B. PHACOPIDELLINAE Delo, n. subf.

Genera *Phacopidella*, Reed, s.s., *Denckmannites* Wedekind, *Dienstina* R. and E. Richter, *Ductina* R. and E. Richter, *Adastocephalum* Mitchell.

Subfamily C. ACASTINAE Delo, n. subf.

Genera *Acaste*, Goldfuss, s.s., *Acastella* Reed, *Phacopina* Clarke, *Scotiella* Delo, n. gen., *Kloucekia* Delo, n. gen., *Acastoides* Delo, n. gen., *Ormathops* Delo, n. gen.

Subfamily D. CALMONINAE Delo, n. subf.

Genera *Calmonia* Clarke, *Pennaia* Clarke, *Anchiopella* Reed, *Proboloides* Clarke, *Typhloniscus* Salter, *Probolops* Delo, n. gen., *Schizostylus* Delo, n. gen.

Family 2. DALMANITIDAE Delo, n. fam.

Subfamily A. DALMANITINAE Reed

Genera *Dalmanites*, Barrande, s.s., *Dalmanitina*, Reed, s.s., *Odontochile*, Hawle and Corda, s.s., *Malvernia* Delo, n. gen., *Eudolatites* Delo, n. gen.

Subfamily B. SYNPHORINAE Delo, n. subf.

Genera *Synphoria* Clarke, *Probolium* Oehlert, *Corycephalus* Hall and Clarke, *Odontocephalus* Conrad, *Coronura* Hall and Clarke,

Anchiopsis Delo, n. gen., *Trypaulites* Delo, n. gen., *Dalmanitoides* Delo, n. gen.

Subfamily C. ASTEROPYGINAE Delo, n. subf.

Genera *Asteropyge* Hawle and Corda, *Metacanthus* Hawle and Corda, *Comura* R. and E. Richter, *Kayserops* Delo, n. gen., *Greenops* Delo, n. gen., *Hadrorachus* Delo, n. gen., *Cryphaeoides* Delo, n. gen.

Subfamily D. PTERYGOMETOPINAE Reed

Genera *Pterygometopus* Schmidt, *Chasmops* McCoy, *Monorakos* Schmidt, *Calyptaulax* Cooper, *Eomonorachus* Delo, n. gen., *Achatella* Delo, n. gen., *Calliops* Delo, n. gen.

Subfamily E. ZELISZKELLINAE Delo, n. subf.

Genus *Zeliszkella* Delo, n. gen.

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JOURNAL OF PALEONTOLOGY, VOL. 9, NO. 5, PP. 421–423, PL. 48, JULY, 1935

NEW PHACOPINAE FROM THE DEVONIAN OF OKLAHOMA AND IOWA

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ABSTRACT

Two new species of *Phacops*, previously assigned to *P. logani* and to *P. rana* are described from the Haragan formation of Oklahoma and the Cedar Valley formation of Iowa. A second new species from the Haragan is tentatively placed in *Reedops*. If substantiated, it marks the only record of the genus from the Devonian of North America.

During a recent study of the Phacopidacea, the writer has had occasion to examine critically specimens from Devonian strata of various portions of North America. This examination has revealed that some forms commonly allocated to *Phacops logani* and to *P. rana* cannot be considered as belonging to these species.

The writer wishes to acknowledge his debt to Professor Charles E. Decker of the University of Oklahoma, and to Professor A. K. Miller of the University of Iowa for loan of the specimens studied; and to Professor Percy E. Raymond of the Museum of Comparative Zoology for his valuable advice and criticism.

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SYSTEMATIC DESCRIPTIONS

Superfamily PHACOPIDACEA Delo
Family PHACOPIDAE Hawle and Corda
Subfamily PHACOPINAE Reed

Genus REEDOPS R. and E. Richter

The genus *Reedops* R. and E. Richter, 1925, was first established by Wedekind in 1911, under the name *Reedia*, which was found subsequently to be preoccupied by *Reedia* Ashmead, 1904. The genotype is *Phacops bronni* Barrande, and the diagnostic feature of the genus is the absence of the subcranial furrow and of the marginal ridge under the glabella. In addition to the Bohemian species, Wedekind has later assigned several species from the Kellerwald to *Reedops*, but the genus has been unknown hitherto in North America.

REEDOPS? DECKERI Delo, n. sp.

Plate 48, figure 1; Text-figure 1

Subcranial furrow absent in front, anterior marginal ridge between suture and subcranial furrow flattened. Cephalon moderately convex for genus, not conspicuously protuberant in front; trace of first pair of lateral furrows lost because of imperfect preservation; second pair very distinct; third pair deep, continuous; third pair of lateral lobes strongly detached, depressed, with a pair of depressed distal tubercles. Nuchal furrow about as prominent as third pair; nuchal lobe broad, elevated about to level of glabellar surface. Eyes large, with about 140 facets, occupying anterior portion of cheeks, not attaining glabellar level; separated from cephalic border by a narrow furrow. Posterior border furrow very conspicuous, surrounding a tuberculated cheek area behind the eyes.

Thororachis highly arched, each annulation bearing a distal pair of knots, similar to those in *Phacops logani*.

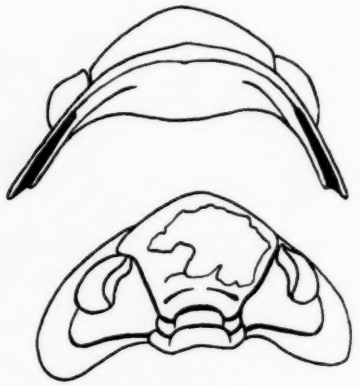

FIG. 1.—*Reedops? deckeri* Delo, n. sp., holotype. Subcephalic view, ×2, showing the mesially incomplete subcranial furrow; cephalon, ×2, showing the large cheek area behind the eyes.

Pygidium moderately convex, broadly rounded, with narrow, elevated pygorachis not reaching posterior margin, and consisting of 7 plus 2 annulations; 5 pairs of broad, flat, indistinctly furrowed pleural ribs, last pair indistinct; interpleural furrows narrow, but distinct.

Entire carapace covered with closely set granulations, coarsest on cephalon, covering all but posterior cephalic border. Finer granulation scattered thickly over each thoracic and pygidial segment, and pygidial border. Each branch of the furrowed pleural ribs bears a row of granules.

Discussion.—Several incomplete specimens of this species from the Haragan formation (Helderberg) in sec. 30, T. 2 S., R. 3 E., Oklahoma, (Holotype, Univ. Oklahoma A10,301; paratype, Univ. Oklahoma A10,302) have been referred previously to *Phacops logani* Hall.

The principal features which differentiate *Reedops? deckeri* from other similar North American species are the large cheek field between the eyes and the posterior border furrow, the nature of the granular ornamentation, and the absence of the frontal subcranial furrow.

The writer's allocation of this species to *Reedops* is tentative because the specimens have very large eyes and a flattened frontal border. Typical species of *Reedops* have small eyes, more or less flattened against the cheek, and no appreciable frontal marginal ridge.

Genus PHACOPS Emmrich

PHACOPS IOWENSIS Delo, n. sp.

Plate 48, figures 4, 5

Glabella narrowly curved in front, moderately convex for the genus; third pair of lateral furrows very distinct, curved anteriorly; second pair discernible; third glabellar lobes broadened mesially, conspicuously tuberculate. Eyes large, with 35 to 40 facets; bounded posteriorly by a tuberculated, ridge-like swell in cheek area in front of posterior marginal furrow. Entire cephalon cov-

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EXPLANATION OF PLATE 48

FIGS. 1—*Reedops? deckeri* Delo, n. sp., pygidium, ×2, showing characteristic ornamentation (p. 421)

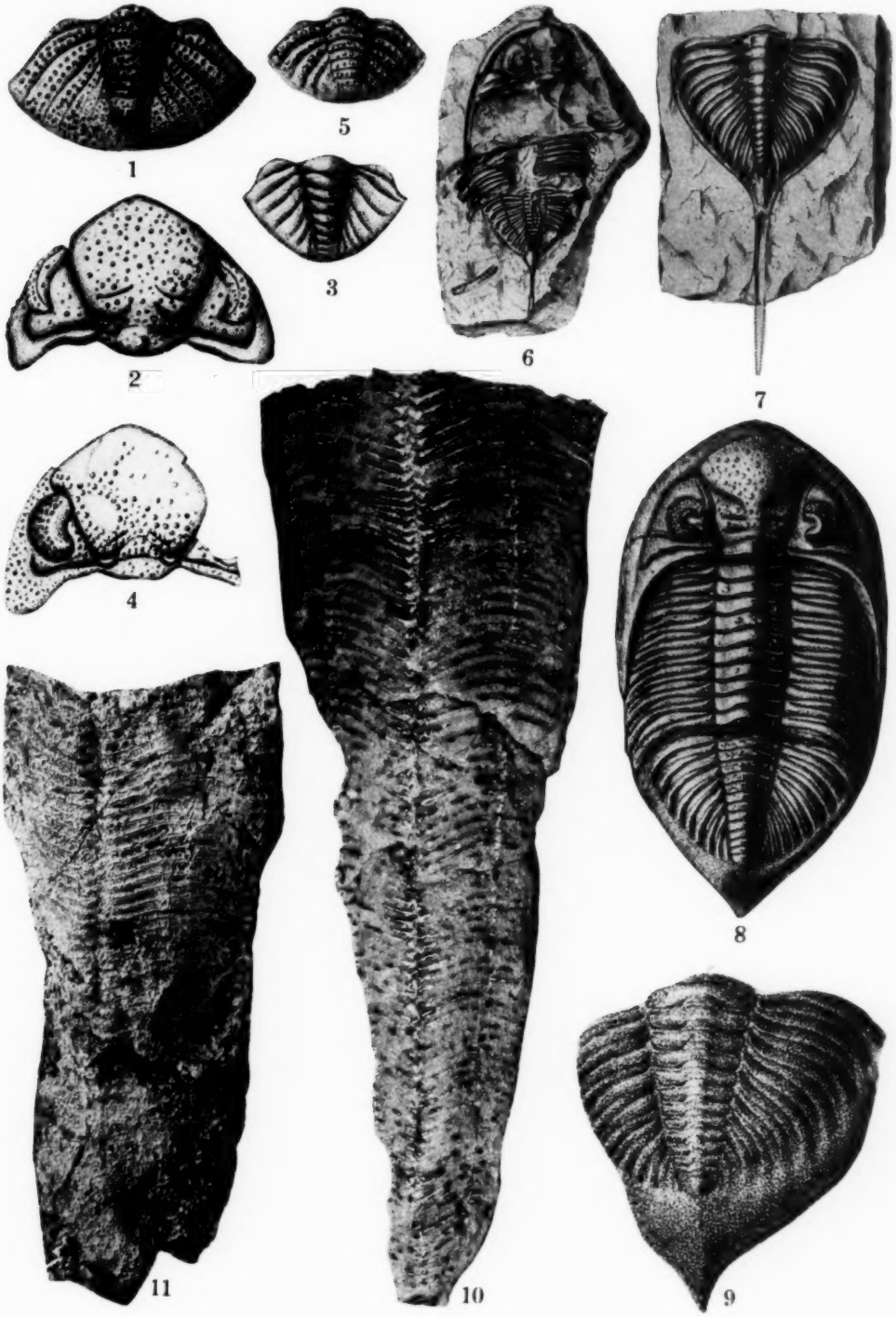
2, 3—*Phacops raymondi* Delo, n. sp. 2, Holotype cephalon; 3, paratype pygidium with characteristic narrow, elevated pygorachis; both ×2. (p. 423)

4, 5—*Phacops iowensis* Delo, n. sp. 4, Cephalon of holotype; 5, paratype pygidium showing ornamentation; both ×2. (p. 422)

6, 7—*Dalmanites caudatus* (Brünnich) (*Asaphus longicaudatus* Murchison), from Murchison (1839, pl. 14, figs. 12, 13). (p. 425)

8, 9—*Odontochile vulgaris* Salter. 8, *Phacops* (*O.*) *caudatus* var. *vulgaris* Salter, from Salter (1864, pl. 3, fig. 5). 9, *Asaphus caudatus* Brongniart, after Brongniart (1822, pl. 2, fig. 4D). (p. 425)

10, 11—*Conularia kaibabensis* McKee, n. sp. 10, Holotype, ×1; 11, paratype, ×2. (p. 428)



Delo, Phacopid Trilobites
McKee, Permian *Conularia*

ered with sharp tubercles of various sizes.

Thorax strongly tuberculated.

Pygidium with 6 to 7 moderately narrow, strongly arched pygorachial annulations, 4 to 5 pairs of pleural ribs. Rather prominent tuberculation on all ribs and annulations, and irregularly distributed around the posterior border.

Discussion.—The name *iowensis* is proposed for specimens from the Devonian strata of Iowa and adjacent regions, assigned previously to *P. rana* (Green), that differ from it in more prominent and widespread tuberculation of the cephalon, smaller number of eye facets (a specimen of *P. rana* of similar size has about 60 facets), more convex and more strongly tuberculated pygidium.

The holotype is an almost complete specimen, somewhat crushed but retaining one side of the cephalon intact, from the Cedar Valley formation at Linn Junction, Iowa (State Univ. Iowa, 9–266).

PHACOPS RAYMONDI Delo, n. sp.

Plate 48, figures 2, 3

Glabella protruding anteriorly in a sharp curve; anterior marginal ridge wide; subcranial furrow narrow, continuous. Second pair of lateral furrows easily discernible; third pair interrupted mesially and curved forward slightly; third pair of glabellar lobes narrow, depressed below the glabellar level, indistinctly detached, bearing a row of widely spaced, tuberculose granules; distal portions of lobes indistinctly detached from mesial portion, each bearing a large tubercle. Nuchal furrow narrow; nuchal lobe long, highly arched, bearing a prominent mesial tubercle and a number of scattered smaller tubercles. Posterior marginal furrow conspicuous, curving forward laterally around a raised, tuberculate cheek area behind eye. Palpebral lobes broadly swollen, higher than palpebrum. Eyes large, with about 90 facets, separated from cephalic border by a broad, shallow furrow. A rudimentary knot just within margin of general angle. Entire cephalon, except for genal and lateral margins, covered with prominent tuberculose ornamentation, most prominent on the glabella.

Thororachis prominent, each annulation bearing small scattered tubercles.

Pygidium with narrow, very prominent pygorachis, consisting of 7 plus 1 or 2 annulations, ending abruptly; dorsal furrows well defined; 5 plus 1 pairs of well defined pleural ribs; anterior 3 indistinctly furrowed, bearing small granulations; interpleural furrows deep, distinct.

Discussion.—This species has been confused commonly with *P. logani* Hall, but differs in the more pointed glabella, wider frontal marginal ridge, narrower subcranial furrow, absence of distal knots on the thororachial annulations, and narrower, more prominent pygorachis.

It resembles *P. iowensis* Delo superficially, but differs in the wider, smooth genal border, less elevated eyes with more numerous facets, elevated and tuberculose nuchal lobe, and relative absence of pygidial ornamentation.

The types are from the Haragan formation (Helderberg) in sec. 20, T. 2 S., R. 3 E., Arbuckle Mountain region, Oklahoma. Holotype, Univ. Oklahoma A10,304; paratype, Univ. Oklahoma A10,305.

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THE GENOTYPE OF *DALMANITES*

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ABSTRACT

The genotype of *Dalmanites* Barrande, 1852, *Trilobus caudatus* Brünnich, 1781, has been confused by later writers with *Asaphus caudatus* Brongniart, 1822. *Asaphus longicaudatus* Murchison, 1839, is identical with Brünnich's species and hence a synonym. *A. caudatus* Brongniart was called *Phacops* (*Odontochile*) *caudatus* var. *vulgaris* by Salter in 1864; this variety is now elevated to specific rank.

Dalmanites was established by Barrande (1852, vol. 1, Additions, p. 919) as a substitute for the preoccupied *Dalmania* Emmrich (1845, p. 40). He had previously (1852, p. 529) designated *Trilobus caudatus* Brünnich, 1781, as the genotype of *Dalmania*, and it therefore stands as the genotype of *Dalmanites*. Since that time the genus has been subjected to repeated refinement. Reed (1905, p. 7) separated the more primitive species to constitute the genus *Dalmanitina*, with *D. socialis* as the genotype. More recently, R. and E. Richter (1931, p. 141) have redefined *Dalmanites*, and have re-established the genus *Odontochile* Hawle and Corda, 1847, the name of which had been thought preoccupied. They have also noted the intermediate position of *Dalmanites* in the phylogenetic sequence *Dalmanitina* (Ordovician), *Dalmanites* (Silurian), and *Odontochile* (Devonian).

Dalmanites, in its restricted sense, may then be defined as follows:

Dalmanitinae with genal spines, and an elongate, non-denticulate hypostoma; pygorachis with from 10 to 16 annulations; pygidium usually mucronate; pygidial doublure narrow.

This definition restricts the genus to species of the type of *Dalmanites caudatus* (Brünnich).

Reference to Brünnich's description of the genotype reveals a misconception of long standing regarding the exact identity of *D. caudatus*. Brünnich described and figured a cephalon and pygidium said to have come from "one mile from Colebrookdale, England, in a yellow-gray clay." The pygidial spine is long and slender, and equals one-half the total length of the pygidium. The pygorachis is narrow, with 16 annulations, and the cephalon shows traces of a short frontal process which had been broken (fig. 1). Thus, in all major details of both description and figure, the holotype of *D. caudatus* does not agree with the specimens figured by Brongniart as *Asaphus caudatus* (1822, p. 22, pl. 2, figs. 4a–d), by Salter as *Phacops* (*Odontochile*) *caudatus* and varieties (1864, p. 49, pl. 3, figs. 4–18; pl. 4,

figs. 1–5), or by later writers as *Dalmanites caudatus*. (See Pl. 48, figs. 8, 9.)

D. caudatus, as figured by Brongniart, has a relatively broad pygorachis with 11 to 12 annulations. The terminal spine is short, triangular, and acute. The *D. "caudatus"* described by all later writers is similar to this specimen, but not to the holotype described by Brünnich.

It is unfortunate that Barrande (op. cit.), in establishing the genotype of *Dalmanites*, did not refer to Brünnich's original paper. It appears that he was misled by Brongniart's figure of *Asaphus caudatus*, a pygidium from Dudley, England. Salter (op. cit.) figured more complete material from the same locality, and applied the varietal name *vulgaris* to the sort figured by Brongniart. The Richters (op. cit.), in their recent discussion of *Dalmanites*, have also apparently failed to recognize the discrepancy between the original description and figures published by Brünnich, and the concepts of later authors.

Murchison (1839, p. 656, pl. 14, figs. 11–14) had meanwhile described a new species, *Asaphus longicaudatus*, which agrees in all major details with the *Trilobus caudatus* figured by Brünnich in 1781 (See Pl. 48, figs. 6, 7). The types of these species were found in strata of the same age, and occur at the same localities. Hence it appears that *A. longicaudatus* Murchison and *Trilobus caudatus* Brünnich are synonymous, and the former is invalid.

As a result, the species figured by Brongniart and later writers as *A. caudatus* or *D. caudatus*, is not conspecific with *Trilobus caudatus*, the genotype of *Dalmanites*. It is suggested, therefore, that the varietal name *vulgaris*, applied by Salter

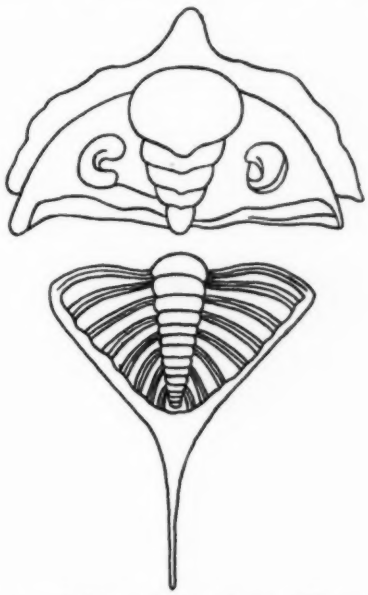

FIG. 1.—*Dalmanites caudatus* (Brünnich) (*Trilobus c.* B.), cephalon and pygidium, after Brünnich (1781).

(1864, p. 51) to the common representatives of the species, be given specific rank. Hence the synonymy now stands: *Trilobus caudatus* Brünnich = *Asaphus longicaudatus* Murchison = *Dalmanites caudatus* (Brünnich). *Asaphus caudatus* Brongniart = *Phacops* (*Odontochile*) *caudatus* var. *vulgaris* Salter = *Dalmanites caudatus* of later writers = *Dalmanites vulgaris* (Salter).

Considered from an evolutionary point of view alone, *D. caudatus* (Brünnich) is not the most satisfactory genotype for *Dalmanites*. This

species stands rather closer to the Lower Devonian *Odontochile* than to the Ordovician *Dalmanitina*. It has a proportionally narrower pygorachis, and the number of annulations (16) is somewhat larger than is the general rule in *Dalmanites* s. str. According to the rules of taxonomy, however, this species must stand as the genotype of *Dalmanites*.

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JOURNAL OF PALEONTOLOGY, VOL. 9, NO. 5, PP. 427–429, PL. 48, JULY, 1935

A CONULARIA FROM THE PERMIAN OF ARIZONA

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ABSTRACT

Conularia kaibabensis is the first species of the genus to be reported from American Permian rocks.

The recent discovery of a species of *Conularia* in the Kaibab limestone of northern Arizona is of especial interest since, so far as the writer has been able to determine, it represents the first species of this genus to be reported from the Permian rocks of America.

Several Permian species of *Conularia* have been reported from the Old World. Three were discovered in India, including two that had previously been described from Australia. In both places they were found in the beds immediately overlying glacial boulder clay and representing the first invasion of the sea following the period of glaciation. Although of large size, they do not resemble very closely the Kaibab form, and are mentioned here because of their similar age.

The species of *Conularia* here described is based on two specimens. One of these, a large individual, was found in 1928 by Dr. Charles Merriam near Bright Angel Point, on the north side of Grand Canyon, in white sugary sandstone near the top of the "B" member, or upper massive limestone, of the Kaibab limestone. The other specimen, a poorly preserved one, had previously been collected by Dr. C. D. Walcott from gray chert in a cherty limestone of the same member at a locality near Shinumo Canyon, some miles west of Bright Angel Point. It was subsequently deposited in the collection of the U. S. Geological Survey and, having recently come to light, has been loaned to the writer for examination through the courtesy of Dr. George H. Girty. The writer is indebted to Dr. C. E. Resser for the photograph of this specimen.

This paper is published with the permission of the Director, National Park Service. The manuscript was received by the editor of the Journal February 25, 1935.

CLASSIFICATION

An attempt to classify the *Conulariae* into convenient groups has been made by Holm (1) and the results used by Slater (2). The three principal sections used in this classification are defined as follows: *Laeves*, shell without transverse ornamentation, except growth lines; *Moniliferae*, ornamentation consisting exclusively of transverse ridges or of tubercles arranged in transverse rows, without finer longitudinal ridges; *Cancellatae*, ornamentation cancellated, with coarse transverse main ridges, forming obtuse angles across the faces and finer and lower longitudinal ridges connecting the former; ornamentation visible to naked eye.

The species from the Kaibab limestone belongs to Holm's section 2, the *Moniliferae*. This group is represented by numerous species and ranges from Ordovician time at least to the closing stages of the Paleozoic era.

SYSTEMATIC DESCRIPTION

CONULARIA KAIBABENSIS McKee, n. sp.

Plate 48, figures 10, 11

Shell large, in the form of an elongated four-sided pyramid, rhombic in cross-section. Two of the opposite sides slightly wider than the other two and their lateral margins diverge towards the aperture at an angle of about 4½°. The obtuse angles bordering each marked by rather deep furrows.

Two sets of striae or costae on each side converge from the margins towards the aperture, then swing partially back as they approach the middle of the face; here they reach an indistinct longitudinal sulcation where they sometimes alternate, sometimes meet. A noticeable feature of this species and one which is absent on most if not all of the closely related Lower Carboniferous forms, is at the lateral margins where the costae make an abrupt turn of about 60° toward the aperture of the shell, thus forming a sharp angle in outline.

Costae are smooth, raised, with flat or nearly flat upper surfaces; grooves between them concave, rounded, and three or more times the width of the costae. About 19 costae in a space equal to the width of the side where they are located, or 16 to the inch near the aperture.

Dimensions of specimen from Bright Angel Point, selected as holotype: Length, 5.7 in. (incomplete at both ends); breadth near wide end, narrow side, 1.0 in.; breadth near wide end, wide side, 1.2 in.; breadth near narrow end, wide side, 0.5 in.; divergence of margins, 4½°.

Comparisons.—A number of species of *Conularia* described from the Lower Carboniferous of the Mississippi valley resemble *C. kaibabensis* in general appearance and large size. *C. missouriensis* Swallow and *C. marionensis* Swallow differ from the Kaibab form principally in having less parallel, more diverging margins (about 18° as compared with 4½°). Other differences are found in the presence of granulations on the costae of *C. marionensis* and in the high and sharp, rather than low, flat costae of *C. missouriensis*. Also, in the latter there are only about half as many costae (ten) in the distance equal to the shell width, while in both species the intercostate furrows appear to be proportionately narrower than in *C. kaibabensis*. *C. osagensis* Swallow differs from *C. kaibabensis* in general shape since two of its opposite sides are twice as wide as the other two. Furthermore, it has ridges along the middle of the wider sides and has more highly convex costae on the narrower sides. *C. subcarbonaria* Meek and Worthen, *C. multicostata* Meek and Worthen, *C. byblis* White, and probably also *C. verneuilli* Emmons (no description and rather inadequate figure) all have more numerous costae than has *C. kaibabensis*. *C. subcarbonaria* is described as having them crenulated and close together with ten in the space of 0.2 in. near the shell middle. Also, it has a higher angle of divergence (18°) and is shorter. *C. multicostata* has even less widely separated costae. *C. byblis* has 45 to 50 costae to the inch according to Herrick, 56 to 128 according to Winchell, and has 60 to 70 granulations per inch along the crests of these. *C. "gracilis"* Herrick (name preoccupied) has ridges ornamented with closely-set bars parallel to the shell length and appears to be proportionately narrower than *C. kaibabensis*.

Of the Permian species from Australia and India, *C. laevigata* Morris is rectangular, not square, in section; has smooth ribs with regular distribution, 10 or 12 to 10 mm., and an apical angle of 15°. Its ribs are essentially straight, not curved. *C. tenuistriata* McCoy is lozenge-shaped

with two broad and two very narrow sides, has smooth straight plications but intervening grooves with fine oblique striations. It has an apical angle of 10° and has 19 to 20 plications to 10 mm. *C. warthi* Waagen is smaller (3 inches), has an apical angle of 12°, ribs ornamented with fine granulations, interspaces with transverse plications. It is rhomboidal with equal sides; has 11 to 16 ribs to 10 mm.

Horizon and Locality.—Middle Permian, Kaibab formation, near top of "B" member or upper massive limestone, Grand Canyon, Arizona.

Types.—Holotype, Grand Canyon Nat. Park Mus., FK211; paratype, U. S. Geol. Survey Carb. Paleont., 6531.

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JOURNAL OF PALEONTOLOGY, VOL. 9, NO. 5, PP. 430–433, JULY, 1935

A PLIOCENE OPHIURAN FROM TRINIDAD

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ABSTRACT

Arm-plates of *Ophioderma* sp. are described from the Matura formation (late Pliocene) of Trinidad.

Little work has been done during the current century on fossil ophiurans as a group, and virtually none on the identification of the detached plates. It is of interest, therefore, to record the observations presented here, though they are somewhat indefinite. The specimens studied were obtained from a small sample of foraminiferal material collected from the Matura formation at its type locality, Matura Bay, Trinidad, B.W.I., by Dr. J.A.Tong, and sent to the Johns Hopkins University for examination.

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OPHIURAN PLATES

The ophiuran test is made up of a great number of different plates, and the classification of the Recent forms is based largely, though none too successfully, on the external arrangement of these plates rather than on the character of the plates themselves. Commonly the plates become dissociated during fossilization and are found scattered. The most numerous in the individual animal, and hence most common as fossils, are those that make up the arm. Each arm-segment, of which there may be as many as 65 per arm, is composed of six plates: two lateral, one dorsal, one ventral, and two fused plates—the vertebral ossicle—enclosed by the other four plates. Beside the arm-plates, there are often found the radial shields, oral shields, jaws, comb, genital, side mouth shields, and numerous varieties of disk plates (1).

The writer believes that when enough work has been done on the characters of the plates, these will supply a satisfactory basis for classification.

AGE AND PRESERVATION OF THE SPECIMENS STUDIED

The Matura formation has been discussed by Liddle (2) and Waring (3). It is typically exposed as an iron-cemented coquina about ten feet thick, though its maximum thickness may be as much as 200 feet. Guppy (4) thought it was probably of late Pliocene age because 10 per cent of the fauna is extinct, and because the fauna is dwarfed. War-

ing (3) agrees with this, but makes the reservation that it may prove to be of Pleistocene age. The writer assigns it for convenience to the late Pliocene.

Guppy considered the dwarfing of the fauna of the Matura formation to be due to cold waters derived from the northern ice sheet. He placed the depth of deposition at 20 to 50 fathoms. Of the associated fossils Guppy lists about 100 species, including "a few spines and fragments of echinoderma."

The sample at my disposal has yielded numerous vertebral ossicles, lateral arm-plates, and one ventral arm-plate of an ophiuran; and several sorts of plates of a comatulid crinoid. All of the ophiuran plates are abraded, and nearly all are more or less coated with iron oxide.

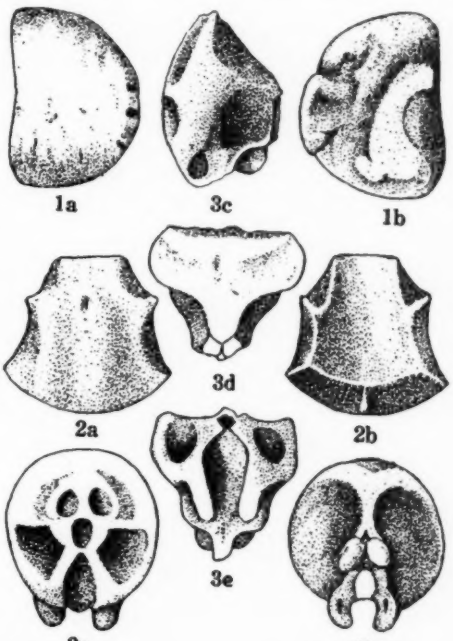
SYSTEMATIC DESCRIPTION

OPHIODERMA sp.

Text-figures 1–3

Lateral arm-plates: The first three lateral arm-plates differ from the remaining later plates, which grade gradually from the mature plate to young ones. The plate figured (figs. 1*a*, *b*) is a mature plate. Outline lunate; adoral margin concave; dorsal, ventral, and aboral margins convex, the last most convex. Outer surface smooth, arched transversely to the axis of the arm; adoral margin with slight indentation due to a short groove on surface; dorsal and ventral margins smooth; aboral margin with numerous small pits that served as sockets for the spines; number of pits not determinable because of abrasion. Internal surface with a ridge extending from aboral-ventral corner to adoral-dorsal corner, rising as a knotted apophysis ventrally and fading near dorsal margin; two slight grooves passing from aboral margin and dividing it into thirds; surface concave transversely to axis of arm. Height, 0.98 mm.; width at middle, 0.82 mm.

Ventral arm-plate: Outline a truncated triangle, the line of truncation forming the adoral margin; aboral margin twice the length of the adoral, strongly convex;



FIGS. 1–3—*Ophioderma* sp., arm-plates, ×24, Matura formation, Trinidad, B.W.I. 1, Lateral arm-plate; *a*, exterior view; *b*, interior view. 2, Ventral arm-plate; *a*, ventral view; *b*, dorsal view. 3, Vertebral ossicle; *a*, adoral view; *b*, aboral view; *c*, lateral view; *d*, dorsal view; *e*, ventral view.

lateral margins bisinuate, the adoral sinus shorter than the aboral. External (ventral) surface smooth, arched slightly transversely to long axis of plate. Internal (dorsal) surface strongly concave transversely to long axis of plate; aboral margin abruptly bevelled, with a narrow, tooth-like ridge at center for articulation with adjacent ventral arm-plate; lateral margins slightly bevelled, strongly disin-

uate. Length, 0.85 mm.; width at aboral margin, 0.98 mm. The location of this single plate (figs. 2*a*, *b*) in the series of ventral plates is indeterminate. Since the illustration was made an aboral-lateral corner has been broken.

Vertebral ossicle: The specimen figured (figs. 3*a-e*) is the best preserved of those found, but is somewhat abraded and has lost some of its original features. The terminology used is defined in an earlier paper by the writer (1). Adoral aspect (fig. 3*a*) circular in outline, notched ventrally by the lower canal-furrow; upper canal-furrow apparently obliterated by abrasion; surface relatively flat, with a deep, oval pit at center that serves as a socket for the zygosphene of the adjacent ossicle, and above it (dorsal) two triangular pits that serve as sockets for the zygocondyles of the adjacent ossicle; a horizontal ridge on each side of the central pit extending to the lateral margins and dividing the alar region into an upper and lower half, the lower half impressed below the rest of the surface and divided by the lower canal-furrow; posterior hypapophyses visible below the lower alar ridge. Aboral aspect (fig. 3*b*) circular in outline, notched below by lower canal-furrow; upper canal-furrow lacking through abrasion; surface rises from lateral margins to the articulating portion, on either side of which lie two muscle areas; articulating portion with zygosphene and paired zygocondyles; zygosphene subcentral, narrower than the lower canal-furrow, with sides slightly convex; zygocondyles central, rounded in outline, with sides rising abruptly from the parapophyses, aboral surface slightly rounded, line of junction a shallow furrow ending above and below in a small pit; a rounded ridge extending dorsally from the upper pit and separating the parapophyses, broadening dorsally; the large parapophyses forming a circular arc interrupted by the lower canal-furrow and the anterior hypapophyses, and rising on the flanks of the articulating area; anterior hypapophyses small, each with a narrow pit dorsally. Lateral aspect (fig. 3*c*) irregular in outline; on adoral side upper and lower alar regions faintly visible; on aboral side the parapophysis distinguishable above, zygocondyle below it, and zygosphene; anterior hypapophysis indicated by a circular depression near ventral side of ossicle. Dorsal aspect (fig. 3*d*) triangular, with adoral side nearly straight; the parapophyses visible on either side; apex of triangular outline formed by zygosphene, with zygocondyles on either side. Ventral aspect (fig. 3*e*) very irregular, with overhanging, steep sided, lower canal-furrow conspicuous in central portion of ossicle; aboral portion, zygosphene flanked by the zygocondyles; on either side of the adoral portion of canal-furrow, the lower alar region. Greatest length, 0.72 mm.; greatest width across alar region, 0.85 mm.; height between bases of the canal-furrows on the adoral side, 0.64 mm.

Discussion.—Even though these plates are complex and characteristic in appearance, it is difficult to identify them. Numerous dissections of the Recent animals are required before one can be certain even of what genera a group of fossil plates may represent. After much work the writer is able to determine the present material as belonging to the genus *Ophioderma*, but the species is still uncertain, for neither enough Recent nor fossil material is available. Nineteen species of *Ophioderma* are listed by Clark (5), all living at about 500 fathoms. The distribution of the genus is wide, including the Mediterranean region, California, and South Africa. Most of the species are found, however, along the east coast of North and South America, particularly in the Caribbean region.

The well-preserved ventral arm-plate, the absence of certain disk-plates, and the presence of the vertebral ossicle indicate the genus *Ophioderma*. The ventral arm-plate is more like those of *O. brevispinum* than of any other species observed. The absence of conspicuous fossil

disk-plates is significant, for in *Ophioderma* the disk is covered by fine calcareous granules, leaving in some species only the oral shield naked. The edge of the lateral arm-plate, with numerous sockets for spines, also suggests *Ophioderma*, for in this genus spines are numerous.

It would be unwise, with the material now available, to attempt to determine the species. Considerable variation in the arrangement and the exact shape of the apophyses and sockets of the vertebral ossicle is found in different parts of the arm of a single species. Certain similarities are present, however, regardless of position and these are characteristic of a given species. The shape, and location of the zygocondyles and zygosphene in the present specimens are similar to those of *O. brevispinum*. Enough difference may be noted, however, to exclude it from that species.

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JOURNAL OF PALEONTOLOGY, VOL. 9, NO. 5, PP. 434–446, JULY, 1935

GRAPTOLITES FROM THE SILURIAN OF OKLAHOMA

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ABSTRACT

The Silurian Henryhouse shale of Oklahoma has yielded fifteen graptolites and three phyllocarid crustaceans. Of the graptolites six are new. The relative abundance of *Monograptus* is notable as linking the fauna with that of the lower Ludlow of England.

Graptolites have been known for a considerable period of time in the Arbuckle Mountains of Oklahoma from the Simpson formations, the Viola limestone, and the Sylvan shale, all of Ordovician age. The Silurian graptolites of the Henryhouse shale have remained almost unknown, however. A few of them had been discovered in 1913 by students from the University of Oklahoma, but had remained unstudied. The rediscovery by J. O. Beach and the writer in July, 1933, of the fauna in the Henryhouse shale came as the result of a more detailed measurement and study of the Silurian formations of Oklahoma in response to a request from Dr. Charles K. Swartz for the writer to serve with him on the Silurian Committee of the National Research Council.

Acknowledgments.—As this fauna was studied in detail in the New York State Museum, the writer is greatly indebted to Dr. C. C. Adams, the Director, for making the facilities of the Museum available. He is especially indebted to Dr. Rudolf Ruedemann for making some of the drawings, and for assisting with the descriptions; to Messrs. E. J. Stein and J. W. Stovall for photographing; to the National Research Council for funds to defray part of the expenses of this study; to the University of Oklahoma Research Committee for paying part of the field expenses; and to Messrs. John Fitts, J. O. Beach and Henry Phillips for assistance in the field.

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STRATIGRAPHY

The Silurian outcrops of Oklahoma lie in the Arbuckle Mountains (in the south-central part of the state), and in the eastern part of the state. In the Arbuckle Mountains two thin formations, the Chimneyhill limestone and the Henryhouse shale, may be seen in numerous outcrops scattered throughout Murray, Carter, Johnston, Coal, and Pontotoc counties. These two formations constitute the lower part of Taff's Hunton formation (38), as divided by Reeds (29). In the eastern part of the state the St. Clair marble crops out at a few places in Cherokee, Sequoyah, and Adair counties, attaining a maximum thickness of about 150 feet.

The Chimneyhill limestone, the lower of the two Silurian formations,

rests upon the Sylvan shale, of Richmond age; and the Henryhouse shale lies beneath the Haragan marl, of lower Helderberg age. The contacts of these formations are apparently conformable, though both Silurian formations are absent at some localities on the south side of the Arbuckle mountains. The Chimneyhill limestone is from 20 to 35 feet thick; the Henryhouse from 50 to 70 feet in the western part of the mountains, though seldom 20 feet in the eastern part. Reeds (29*a*) has credited the Henryhouse with a maximum thickness of 223 feet, and with 180 feet at its type locality on Henryhouse Creek. At this type locality the writer secured a horizontal measurement of 159 feet with a dip of 28°. This would give a thickness of only 76 feet, and in most sections it measures 50 feet or less. It is absent on Sycamore Creek, and absent or very thin at most localities in the eastern part of the mountains.

THE FAUNA

The fauna consist of fifteen species and varieties of graptolites and three caryocarids (described by Ruedemann on pp. 447, 448), as follows:

Dendroidea Nicholson

Ascograptus sp.
Mastigograptus beachi Decker, n. sp.
Mastigograptus sp.
Thallograptus phylloides Decker, n. sp.

Graptoloidea Lapworth

Axonophora Frech

Monograptus bohemicus (Barrande)
Monograptus crinitus Wood var. *exilis* Decker, n. var.
Monograptus dubius (Suess)
Monograptus nilssoni (Barrande)
Monograptus scanicus Tullberg
Monograptus tumescens Wood
Monograptus cf. *ultimus* Perner
Monograptus vulgaris Wood
Monograptus (*Linograptus*) *phillipsi* Decker, n. sp.
Monograptus (*Linograptus*) *phillipsi* var. *multiramosus* Decker, n. var.
Cyrtograptus sparsus Decker, n. sp.

Arthropoda

Phyllocarida Packard

Caryocaris magnus Ruedemann, n. sp.
Caryocaris oklahomensis Ruedemann, n. sp.
Caryocaris sp.

Of the fifteen graptolites here described and illustrated, ten belong to the genus *Monograptus*, a significant fact, for no such assemblage of monograptids has been found heretofore on the North American continent, indeed, not more than two of the individual species have been found here. The three species of *Caryocaris* are of interest because of the very common association of caryocarids with graptolites. In speaking of this association Ruedemann (34) says: "This genus of phyllocarid crustaceans seems to be particularly characteristic of the graptolite shales; it is found only in them."

In comparing the graptolite fauna of the Henryhouse shale with other Silurian faunas of North America one is impressed primarily with the differences rather than the similarities. Only the profusely branching dendroid graptolites are found in Ontario and dendroid species are common in New York and Indiana, whereas not a single dendroid species has been found in Oklahoma. From Hamilton, Ontario, R. S. Bassler (2) has described 52 species and varieties. Of

the 24 species and varieties described by Ruedemann (33) from New York, 10 are common to Ontario. Shrock (36*a*) has compared the fauna of Indiana as follows:

> Of the 16 described species found in Indiana 15 are reported from Hamilton, Ontario; 7 from the Gasport limestone of New York; and 3 from the Rochester shale of New York.

The Silurian fauna of Oklahoma contains none of the Ontario graptolites, only an *Ascograptus* that may be similar to a form from New York, and *Monograptus bohemicus* very much like the *M. falciformis* described by Shrock (36*a*). When Shrock described his species Ruedemann indicated to him that it was very close to the European *M. bohemicus*. After studying many specimens of *M. bohemicus* from the Henryhouse shale, and comparing them with the photographs of Shrock's form, it was concluded that his material probably represents fragments of colonies of *M. bohemicus*. If this conclusion is correct, the Indiana and Oklahoma faunas are linked by this cosmopolitan graptolite.

If *Monograptus bohemicus*, as suggested above, occurs in northern Indiana, the Henryhouse shale may be correlated in part at least with the Mississinewa shale of northern Indiana. Also, because of the relation of the fauna of that shale to Silurian faunas of New York and Ontario, the Henryhouse would seem connected with the Silurian of those two regions.

Monograptus nilssoni is very common in the Henryhouse shale, and Ruedemann has discovered it also in the Silurian of Maine.

Outside of North America, the Henryhouse shale finds its closest correlative in the lower Ludlow shales of Great Britain. Eight species from the Henryhouse shale, *Monograptus bohemicus*, *M. crinitus*, *M. dubius*, *M. nilssoni*, *M. scanicus*, *M. tumescens*, *M.* cf. *ultimus* and *M. vulgaris* are common in this British unit. *M. dubius* and *M. vulgaris* occur also in the top of the next lower British horizon, the Wenlock shales. Three of the species found in Oklahoma and Great Britain are cosmopolitan. *M. dubius* occurs in Sweden, Poland, Germany, Bohemia, Spain, Austria, Italy and Australia; *M. nilssoni* has the same distribution, plus Maine; and *M. bohemicus* the same, except Spain. *Monograptus* (*Linograptus*) *phillipsi* Decker is closely related to the Bohemian form listed by Frech (12) as *Linograptus nilssoni* in so far as branching is concerned, but his form is shown with simple thecae. Possibly other views of Frech's material would show the more complex theca of the Oklahoma species.

LOCALITIES

1. Gray calcareous shale, 8 feet above the base of the Henryhouse shale, on the south side of Cool Creek, in the southwest corner of sec. 36, T. 2 S., R. 2 E., Carter County, Oklahoma.

2. Shale, 17 feet above base of the Henryhouse shale, on Honey Creek, Murray County, Oklahoma.

3. Shale, 5 feet above the base of the Henryhouse shale, on Falls Creek, sec. 33, T. 1 S., R. 2 E., Murray County, Oklahoma.

SYSTEMATIC DESCRIPTIONS

Order 1. DENDROIDEA Nicholson
Family DENDROGRAPTIDAE Roemer
Genus ASCOGRAPTUS Ruedemann, 1925

ASCOGRAPTUS sp.

Figures 1–4

Figured specimens.—Mus. Inv. Paleont. Univ. Oklahoma A2431, A2432.

Several small cylindrical or pear-shaped bodies seem to be most like *Ascograptus similis* Ruedemann (33*a*), though not enough specimens have been found to identify them definitely with this species. The thecae have about the same shape, and in two specimens three thecae are arranged around a central axis in a manner similar to that illustrated from New York. No clear evidence of spiral arrangement is shown, but the aperture of one form is quite like that of *A. similis*, and the specimens compare favorably in size, ranging from 0.75 to 1.0 mm. in length and from 0.25 to 0.5 mm. in width.

Ruedemann suggested the possibility that the Oklahoma specimens are gonothecae of *Mastigograptus*, but decided that the arrangement of the two groups is more like that of *Ascograptus*.

Occurrence.—Rare at locality 1.

Genus MASTIGOGRAPTUS Ruedemann, 1908

MASTIGOGRAPTUS sp.

Figures 5–7

Figured specimens.—Mus. Inv. Paleont. Univ. Oklahoma A2433–A2435.

Three fragments referable to *Mastigograptus* are scarcely good enough to warrant description. Elongate; slender, 0.4 to 0.7 mm. wide; one bifurcates near the base. Carbonaceous rings of two sizes along the axis, the smaller ones, 0.15 to 0.2 mm. in diameter, the larger ones, 0.3, to 0.5 mm. in diameter. Ruedemann suggested that the smaller rings may have been for the attachment of thecae and the larger ones for gonothecae.

These specimens certainly represent a new and different species, though in their slender form they resemble somewhat the much older forms from the Utica shale illustrated by Ruedemann (32*a*).

Occurrence.—Locality 1.

MASTIGOGRAPTUS BEACHI Decker, n. sp.

Figures 8–11

Holotype.—Mus. Inv. Paleont. Univ. Oklahoma A2436.

A profusely branching colony in which the main stem, or coenosarcal canal, is broken and bent back upon itself; when straightened the colony exceeded 40 mm. in length: main stem 0.75 mm. wide, branches 0.1 mm. Larger stem and branches mostly preserved as impressions only, generally lacking all carbonaceous material; in a few places fragments of the relatively thick carbonaceous stems preserved. Entire colony covered with innumerable, tiny, elongate, conical hydrothecae, 0.6 mm. in length; larger gyroform bodies doubtless represent gonothecae (figs. 9–11); both hydrothecae and gonothecae preserved in fairly thick carbonaceous films. Branches with general shape of those of *Mastigograptus tenuiramosus* Ruedemann (32*b*).

In discussing the position of *Mastigograptus*, Ruedemann (32*c*) suggested a closer affinity with Recent hydrozoans than with true graptolites. Chapman also (6*a*) has gone into this relationship and would class them with the hydrozoans.

The species is named for Mr. J. O. Beach, who assisted largely in making collections in the Arbuckle Mountains.

Occurrence.—Locality 1.

Genus THALLOGRAPTUS Ruedemann, 1925

THALLOGRAPTUS PHYLLOIDES Decker, n. sp.

Figure 12

Holotype.—Mus. Inv. Paleont. Univ. Oklahoma A2437.

Rhabdosome of four broadly obvate to wedge-shaped, leaf-like expansions ra-

diating from a common center; diameter, 9 mm.; length of largest lobe, 5 mm., width, 4 mm. The leaf-like lobes consist of a smooth, thick, carbonaceous film perforated by circular pores, and furnished with deeper black, thick, circular nodes of the same size as the pores, 0.1 to 0.2 mm. in diameter.

Only a single specimen has been found, which differs greatly from most graptolites. Ruedemann has compared it with the broader dendroids of algal aspect, such as *Thallograptus phycoides* (Spencer) and *Inocaulus vegetabilis* (Gurley Ms.) Bassler (*2a*). Ruedemann (*33b*) brought together under the genus *Thallograptus* a number of graptolites of general vegetable habit. Because of the nature of the carbonaceous film and regular arrangement of pores and nodes, *T. phylloides* may well be placed in this genus. In general form it may be compared to *Ptilograptus foliaceus* Spencer, as illustrated by Bassler (*2b*), though the Henryhouse form does not show the detailed pinnate branching of the Ontario form. There seems, however, to be a suggestion of such branching where part of the carbonaceous film has been exfoliated.

Occurrence.—Locality 1.

Genus MONOGRAPTUS Geinitz, 1852

MONOGRAPTUS BOHEMICUS (Barrande)

Figures 20–24

Graptolithus bohemicus BARRANDE, *1850*, Graptolites de Bohême, p. 40, pl. 1, figs. 15–18.—SUESS, *1851*, Ueber böhmische Graptolithen, pp. 110–111, pl. 8, figs. 6*a–e*.—HEIDENHAIN, *1869*, Deutsch. geol. Gesell., Zeitschr., vol. 21, p. 149, pl. 1, figs. 4*a–c*.

Monograptus bohemicus (Barrande), GEINITZ, *1852*, Die Graptolithen . . . der Grauwackenformation in Sachsen, p. 36, pl. 2, fig. 41.—TULLBERG, *1883*, Skånes graptoliter, pl. 3, figs. 3–5.—LA TOUCHE, *1884*, Handbook to the geology of Shropshire, p. 77, pl. 18, fig. 573.—GEINITZ, *1890*, Die Graptolithen des mineralogischen Museums in Dresden, p. 14, pl. A, fig. 10.—PERNER, *1899*, Études sur les graptolites de Bohême, pt. 3, sect. *b*, p. 16, pl. 14, figs. 15, 16; pl. 17, figs. 3, 8, 9, 11; text-figs. 17, 18.—WOOD, *1900*, Geol. Soc. London, Quart. Jour., vol. 56, p. 483, text-fig. 25, pl. 25, figs. 27*a*, *b*.—ELLES and WOOD, *1901–1918*, British graptolites, p. 367, text-figs. 239*a–c*, pl. 36, figs. 4*a–d*.—GORTANI, *1920*, Paleontogr. Ital., vol. 26, p. 26, pl. 2, figs. 9, 10.—THOMAS and KEBLE, *1933*, Roy. Soc. Victoria, Proc., n. ser., vol. 45, pt. 2, p. 53.

Pristiograptus bohemicus (Barrande), JAEKEL, *1899*, Deutsch. geol. Gesell., Zeitschr., vol. 41, p. 672, pl. 28, figs. 3–6.—FRECH, *1897*, Lethea Geognostica, vol. 1, pt. 3, p. 644.

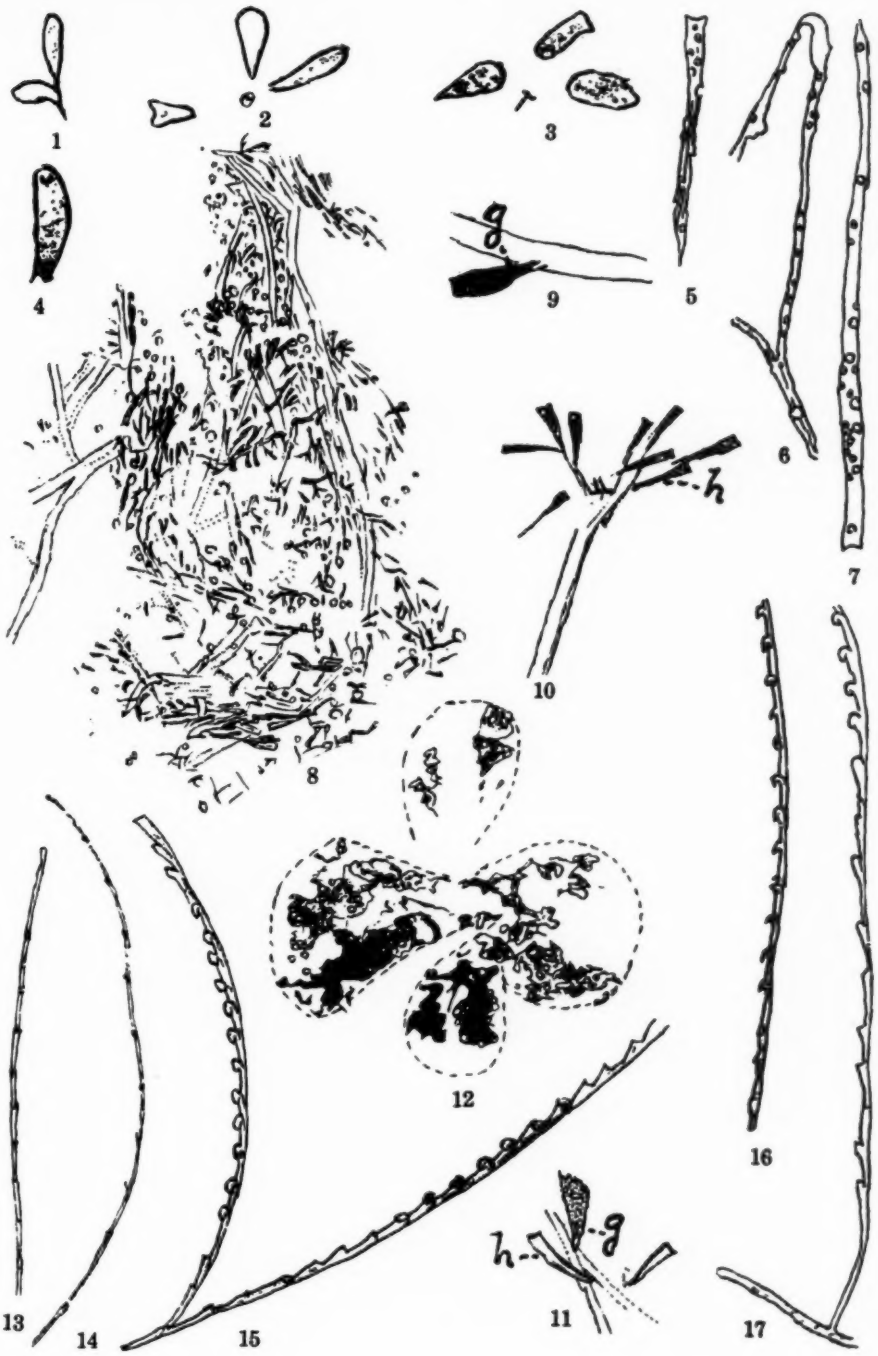
Graptolithus barrandei SCHARENBERG, *1851*, Ueber Graptolithen: Inaug. Diss. (Breslau), p. 15, pl. 1, figs. 5, 5*a*.

Graptolithus scalaris QUENSTEDT, *1881*, Petrefactkunde Deutschlands, vol. 6, pl. 150, fig. 44.

Figured specimens.—Mus. Inv. Paleont. Univ. Oklahoma A2438–A2441.

Mature rhabdosome characterized by a broad concave sweep proximally which grades into a straight or slightly curved distal region; long, relatively large; length, 5 cm. or more, increasing gradually from 0.25 to 2.4 mm. in width. Thecae 11 to 8 in 10 mm., consisting of simple tubes 2 mm. long, 2 to 3 times as long as wide, overlapping one-third to one-half their length; average inclination about 30°, but the English varieties range from 30° to 35°; sicula 1 mm. long; virgella stout. In young individuals the entire rhabdosome curved, the straight distal part being developed only as the colonies become mature.

FIGS. 1–4—*Ascograptus* sp., ×15, locality 1. (p. 437)
5–7—*Mastigograptus* sp., ×4, locality 1. (p. 437)
8–11—*Mastigograptus beachi* Decker, n. sp., locality 1. 8, Holotype, ×4; 9–11, gonothecae (*g*) and hydrothecae (*h*), ×15. (p. 437)
12—*Thallograptus phylloides* Decker, n. sp., holotype ×5, locality 1. (p. 437)
13, 14—*Monograptus crinitus* Wood var. *exilis* Decker, n. var., syntypes, ×4, locality 1. (p. 440)
15–17—*Cyrtograptus sparsus* Decker, n. sp., syntypes, ×4, locality 1. (p. 445)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Occurrence.—In great abundance at all three localities at which graptolites have been found in the lower part of the Henryhouse shale. It has long been known for its common occurrence and wide distribution in the lower Ludlow shales in Great Britain; also in Sweden, Poland, Bohemia, Austria, Germany, France, Italy; and, more recently, from Victoria, Australia.

The Oklahoma occurrence of this cosmopolitan monograptid is the first to be recorded from North America unless *M. falciformis* Shrock, (36*b*) from the Mississinewa shales of northern Indiana, should fall within this species. After comparing the drawings and photograph of *M. falciformis* with the numerous specimens of *M. bohemicus* available from the Henryhouse shale, Ruedemann thinks it is probable that the former falls within the boundaries of *M. bohemicus.*

MONOGRAPTUS CRINITUS Wood var. EXILIS Decker, n. var.

Figures 13, 14

Monograptus crinitus WOOD, *1900*, Geol. Soc. London, Quart. Jour., vol. 56, text-figs. 23*a–d*, pl. 25, figs. 26*a*, 26*b*.—ELLES and WOOD, *1901–1918*, British graptolites, p. 435, text-fig. 298 *a–c*, pl. 44, figs. 3*a–c*.

Syntypes.—Mus. Inv. Paleont. Univ. Oklahoma A2443, A2444.

Elles and Wood have described *M. crinitus* as follows:

Polypary irregularly flexed, very slender, 8 cm. or more in length, widening from a thread-like proximal end to a maximum breadth of about .4 mm. Thecae five to seven in 10 mm. of the type of *M. scanicus* but far more slender. Overlap insignificant. . . . The thecae all show a beak-like apertural termination like that of *M. scanicus*, but are far more elongate and drawn out, the ventral walls running almost parallel with the line of the axis of the polypary.

In the Henryhouse shale, bundles of the filaments occur. Only two fragments are illustrated, and even these do not show full profile view. As the rhabdosomes are only about one-half the width of the English species, 0.1 to 0.2 mm., and as the thecae are a little shorter, 7 to 8 in 10 mm., the new varietal name *exilis* seems warranted for the American forms.

Occurrence.—At all three Henryhouse localities, but it is best preserved and occurs more abundantly at locality 1. In Great Britain *M. crinitus* occurs at Lower Winnington, Shropshire, in the lower Ludlow shales (*M. nilssoni* zone).

MONOGRAPTUS DUBIUS (Suess)

Figures 18, 19

Graptolithus colonus BARRANDE, *1850*, Graptolites de Bohême, p. 48, pl. 2, fig. 5.

Graptolithus dubius SUESS, *1851*, Ueber böhmische Graptolithen, p. 115, pl. 9, figs. 5*a*, 5*b*.

Monograptus dubius (Suess) LAPWORTH, *1876*, Geol. Mag., dec. 2, vol. 3, p. 506, pl. 20, fig. 10.—TULLBERG, *1883*, Skånes graptoliter, pt. 2, ser. C, no. 55, p. 29, pl. 1, figs. 28, 29; pl. 2, figs. 20, 21.—HOLM, *1890*, Gotlands graptoliter, vol. 16, pt. 4, no. 7, p. 16, pl. 1, figs. 18–26.—WIMAN, *1893*, Geol. Inst. Upsala, Bull., vol. 1, no. 2, p. 22, pl. 7.—WOOD, *1900*, Geol. Soc. London, Quart. Jour., vol. 56, p. 454, text-fig. 9, pl. 25, figs. 1*a*, *b*.—ELLES and WOOD, *1901–1918*, Monograph of British graptolites, p. 376, pl. 37, figs. 7*a–d*.

Monograptus serra Hopkinson Ms., LAPWORTH *1880*, Annals Mag. Nat. Hist., ser. 5, vol. 5, pl. 4, figs. 6*c*, *d*.

Figured specimens.—Mus. Inv. Paleont. Univ. Oklahoma A2445, A2446.

This species is variable both in length and width. Though the Henryhouse

FIGS. 18, 19—*Monograptus dubius* (Suess), ×4, locality 1. 18, Side view; 19, partial edge view of another specimen. (p. 440)

20–24—*Monograptus bohemicus* (Barrande). 20–22, Specimens, ×2, from locality 1; 23, specimen, ×4, from locality 2; 24, specimen, ×4, from locality 1. (p. 438)

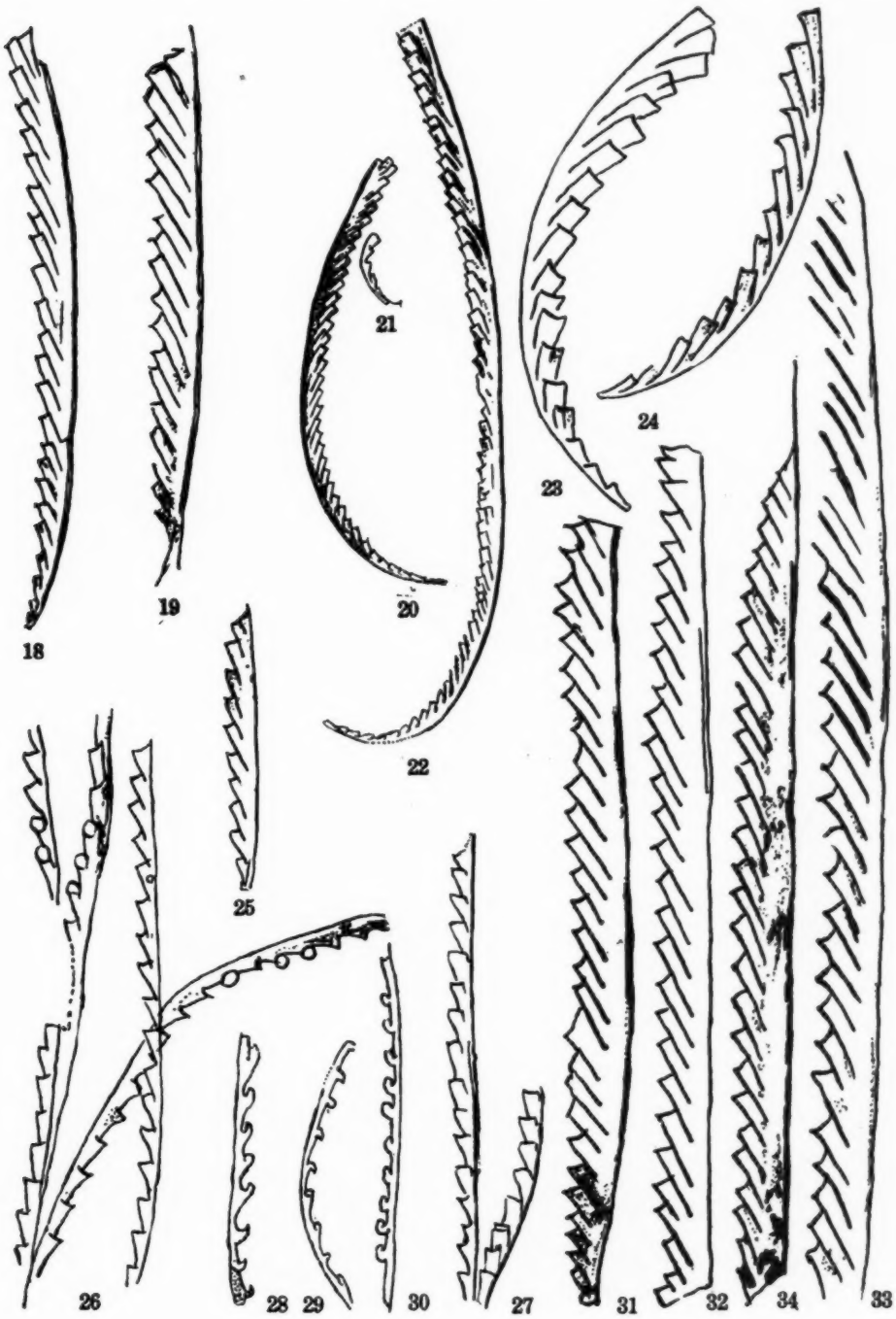
25—*Monograptus* cf. *M. ultimus* Perner, ×4, locality 2. (p. 443)

26, 27—*Monograptus nilssoni* (Barrande), ×4, locality 1. (p. 442)

28–30—*Monograptus scanicus* Tullberg. 28, 29, Specimens, ×4, from locality 2; 30, specimen, ×4, from locality 1. (p. 443)

31—*Monograptus tumescens* Wood, ×4, locality 2. (p. 443)

32–34—*Monograptus vulgaris* Wood, 32, 33, Specimens, ×4, from locality 2; 34, specimen, ×4, from locality 1. (p. 443)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representatives are less than 4 cm. long, the British forms reach 10 cm. A slight curve on the ventral side proximally is characteristic. Though the mature distal portion is generally straight, some of the American as well as some of the British forms show curvature in this region, possibly of a secondary origin.

The longest specimen from Oklahoma measures less than 4 cm., though broken distally, and the different specimens range from 1.5 to 2.3 mm. in width; proximally they measure 0.3 mm., increasing gradually to the mature width in the distance of 8 or 9 thecae. Thecae 11 to 8 in 10 mm., tubes straight, about 3 mm. long, three times as long as wide, and with simple openings, overlapping about one-half their length; sicula 1.7 mm. in length, extending to the level of the second thecal aperture; angle of inclination 30° to 35°. Elles and Wood have well distinguished this species as follows (11*a*):

Monograptus dubius somewhat resembles in its general characteristics *M. vulgaris* and *M. tumescens*, but should be readily distinguished from the former by the proximal ventral curvature, and from the latter by the shorter broader thecae. It has often been confused with *M. colonus*, but the two are easily separated owing to the absence in *M. dubius* of any retroversion of the thecae such as is characteristic of the proximal end of *M. colonus*.

Occurrence.—Both forms illustrated are from locality 1. The British forms have a long range, occurring in both the Wenlock and lower Ludlow shales. It occurs in Sweden, Poland, Germany, Bohemia, Spain, Austria, Italy, and in Victoria, Australia.

MONOGRAPTUS NILSSONI (Barrande)

Figures 26, 27

Graptolithus nilssoni BARRANDE, *1850*, Graptolites de Bohême, p. 51, pl. 2, fig. 16.

Monograptus nilssoni (Barrande), GEINITZ, *1852*, Die Graptolithen . . . der Grauwackenformation in Sachsen, p. 35, pl. 2, figs. 17–20, 24, 25, 28–32(?).—HEIDENHAIN, *1869*, Deutsch. geol. Gesell., Zeitschr., vol. 21, p. 147, pl. 1, fig. 2.—LAPWORTH, *1876*, Geol. Mag., dec. 2, vol. 3, p. 315, pl. 10, figs. 7*a–c*.—HAUPT, *1876*, Die Fauna des Graptolithengesteines, p. 21, pl. 4, fig. 3.—KAYSER, *1878*, Die ältesten Devon-Ablagerungen des Harzes, p. 217, pl. 31, fig. 12.—TULLBERG, *1883*, Skånes graptoliter, pl. 1, figs. 31, 32.—LA TOUCHE, *1884*, Handbook to the geology of Shropshire, p. 78, pl. 18, fig. 576.—GEINITZ, *1890*, Die Graptolithen des mineralogischen Museums in Dresden, p. 13, pl. A, fig. 7 (part), not fig. 8.—PERNER, *1899*, Études sur les graptolites de Bohême, pt. 3, sect. B, p. 7, pl. 17, figs. 1, 2, 7.—WOOD, *1900*, Geol. Soc. London, Quart. Jour., vol. 56, p. 482, text-fig. 24, pl. 25, figs. 28*a*, *b*.—ELLES and WOOD, *1901–1918*, Monograph of British graptolites, p. 369, pl. 37, figs. 1*a–c*.

Pristiograptus nilssoni (Barrande), JAEKEL, *1889*, Deutsch. geol. Gesell., Zeitschr., vol. 41, p. 673, pl. 28, fig. 7.

Linograptus nilssoni (Barrande), FRECH, *1897*, Lethea geognostica, vol. 1, pt. 3, p. 662, fig. 218.

Monograptus scanicus ROEMER (not Tullberg), *1885*(?), Lethea erratica, pl. 9, figs. 13*a*, *b*.

Figured specimens.—Mus. Inv. Paleont. Univ. Oklahoma A2447, A2448.

Rhabdosome slender though sturdy in appearance, attaining a length of several centimeters and a width of 1 mm.; with gentle double curve proximally; straight distally, as a rule. In several instances rhabdosomes were found associated in great numbers in a tangled mass. Frech (12) has illustrated a form he calls *Linograptus nilssoni* in a large spindle-shaped colony in the general shape of a banana crate. Thecae 8 to 9 in 10 mm.; tubes simple, with slight sigmoid curve, 2 mm. long, overlapping about one third their length; apertural margin straight, inclined about 20°; proximal end without sicula, generally narrow, 2 mm. wide.

Occurrence.—At all three localities in Oklahoma. This cosmopolitan Silurian graptolite hitherto has been found in North America only in Maine (Ruedemann Ms.). It has been found in England, Sweden, Germany, Poland, Bohemia, Italy, France, Spain, and Victoria, Australia.

MONOGRAPTUS SCANICUS Tullberg

Figures 28–30

Monograptus scanicus TULLBERG, *1882*, Skånes graptoliter, pt. 2, p. 26, pl. 2, fig. 38.—WOOD, *1900*, Geol. Soc. London, Quart. Jour., vol. 56, p. 479, text-fig. 22*a*, *b*, pl. 25, figs. 25*a*, *b*.—ELLES and WOOD, *1901–1918*, Monograph of British graptolites, p. 435, pl. 44, figs. 2*a–d*.

Figured specimens.—Mus. Inv. Paleont. Univ. Oklahoma A2450–A2452.

Rhabdosomes slender; some slightly, others strongly flexed, with thecae on inside of curve; maximum width, 1 mm. Thecae 8 to 9 in 10 mm., overlapping slightly, up to one-third their length. Some straight fragments reach 7.5 cm. in length, but all found in Henryhouse shale are short.

Occurrence.—Localities 1 and 2. Lower Ludlow shales of Great Britain, with *M. nilssoni* and *M. bohemicus*. It is considered one of the best horizon markers in the Silurian.

MONOGRAPTUS TUMESCENS Wood

Figure 31

Graptolithus colonus NICHOLSON, *1868*, Geol. Soc. London, Quart. Jour., vol. 24, p. 540, pl. 20, figs. 9–11.

Pristiograptus frequens JAEKEL?, *1889*, Deutsch. geol. Gesell., Zeitschr., vol. 41, p. 669, pl. 28, figs. 1, 2.

Monograptus tumescens WOOD, 1900, Geol. Soc. London, Quart. Jour., vol. 56, p. 458, fig. 11; pl. 25, figs. 5*a*, *b*.—ELLES and WOOD, *1901–1918*, Monograph of British graptolites, p. 379, pl. 37, figs. 12*a–d*.

Figured specimen.—Mus. Inv. Paleont. Univ. Oklahoma A2453.

Rhabdosome may reach a length of 4 cm.; characterized by a strong ventral curve in the proximal portion; straight distally; widens rapidly from 0.5 to a maximum of 2 mm. Thecae typically 11 to 9 in 10 mm., 3 mm. long, four times as long as wide and overlapping nearly two-thirds of their length; inclined about 30°.

This form differs from *M. vulgaris* in the marked ventral curvature at the proximal end, in the rapid increase in width, in the smaller angle of inclination, and in the slightly thinner sicula, which is about 2 mm. long and four times as long as wide.

The form illustrated is from 17 feet above the base of the Henryhouse shale on Honey Creek.

Occurrence.—Locality 2. In Great Britain in the lower Ludlow shales.

MONOGRAPTUS cf. M. ULTIMUS Perner

Figure 25

Monograptus ultimus PERNER, *1899*, Études sur les graptolites de Bohême, pt. 3, sect. *b*, p. 13, text-figs. 14*a*, *b*, pl. 16, figs. 4, 5, 11*a*, *b*.—WOOD, *1900*, Geol. Soc. London, Quart. Jour., vol. 56, p. 461, text-fig. 13, pl. 25, figs. 9*a*, *b*.—ELLES and WOOD, *1901–1918*, Monograph of British graptolites, p. 383, text-figs. 253*a–c*, pl. 37, figs. 14*a–d*.

Figured specimen.—Mus. Inv. Paleont. Univ. Oklahoma A2449.

Rhabdosome very small, short, and slender; length not more than 2 cm. and width 1 mm.; straight except for slight ventral curvature proximally. Thecae 12 to 11 in 10 mm., 1.5 mm. long, three times as long as wide, overlapping about one-half of their length; inclined 30° to 40°. Sicula generally conspicuous, reaches to level of aperture of second theca.

Though something like *M. comis* and *M. dubius*, it is a much smaller and more graceful form than either of them.

Occurrence.—Localities 1 and 2; at latter poorly preserved. In Great Britain in the lower Ludlow shales (*M. nilssoni* zone), and in Bohemia.

MONOGRAPTUS VULGARIS Wood

Figures 32–34

Monograptus vulgaris WOOD, *1900*, Geol. Soc. London, Quart. Jour., vol. 56, p. 455, text-fig. 10, pl. 25, fig. 2.—ELLES and WOOD, *1901–1918*, Monograph of British graptolites, p. 378, pl. 37, figs. 10*a–e*.

Figured specimens.—Mus. Inv. Paleont. Univ. Oklahoma A2454–A2456.

Rhabdosomes large, long, and wide; fragments from the Henryhouse shale are less than 5 cm. long, but some British specimens attain a length of 10 cm.; width of mature specimens from 2 to 2.5 mm.; characteristically straight at the proximal end. Thecae rather close-

set, 12 to 9 in 10 mm.; though short in the proximal region, they attain a length of 3 mm. at about the tenth theca; about four times as long as wide and overlap one-half to one-third their length. Sicula 2 mm. long and four times as long as wide. Angle of inclination 35° to 40°.

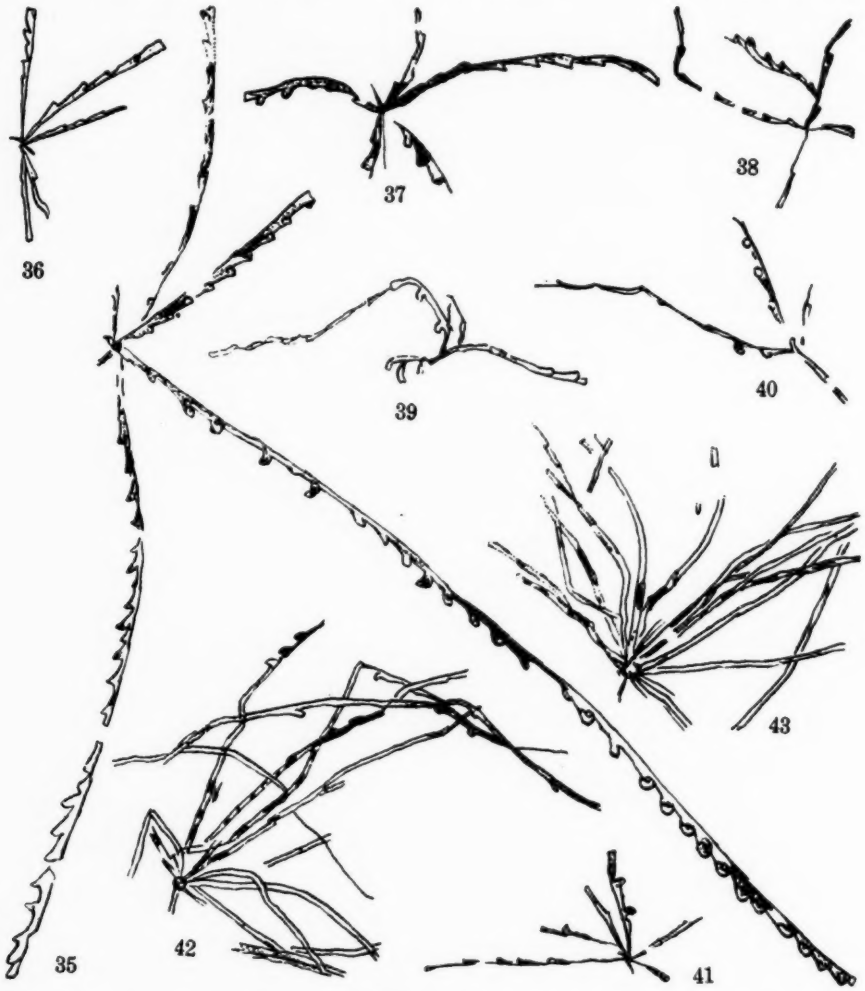
Occurrence.—Localities 1, 2, and 3. In Great Britain in the lower Ludlow shales and in the very top of the Wenlock.

MONOGRAPTUS (LINOGRAPTUS) PHILLIPSI Decker, n. sp.

Figures 35–41

Types.—Holotype, Mus. Inv. Paleont. Univ. Oklahoma A2457; paratypes, A2458–A2463.

Synrhabdosomes generally of five branches radiating from a central point, with their greatest length extending from



FIGS. 35–41—*Monograptus* (*Linograptus*) *phillipsi* Decker, n. sp., ×4, locality 1. 35, Holotype; 36–41, paratypes. (p. 444)

42, 43—*Monograptus* (*Linograptus*) *phillipsi* Decker var. *multiramosus* Decker, n. var., ×4, syntypes from locality 1. (p. 445)

1.5 to 3 cm. Branches of synrhabdosome straight or gently flexed, as a rule, but sometimes bent abruptly; thecae as a rule on the inside of the curve; branches 0.25 mm. wide in dorsal view, 0.5 mm. wide in lateral view. Thecae 11 to 10 in 10 mm., with retroverted and flexed apertures, occupying about three-fourths the length of the thecae and three-fourths the width of the rhabdosomes. Sicula not seen.

The synrhabdosomes are of special interest because the characteristics of *Monograptus* are retained in these compound branching forms. They have still greater significance when it is realized that in all the scores of monograptids described by Elles and Wood, not one exhibits this type of branching. A dozen of these colonies were found, seven of which are illustrated. Ruedemann thinks that the colony grew in gonangial sacks, as described for *Diplograptus* (30), and that the rhabdosomes would thus carry the siculae at the outer ends.

Frech (12) erected the genus *Linograptus* for synrhabdosomes with the thecae of *Monograptus nilssoni*. Elles and Wood (11*b*) consider *Linograptus* a synonym of *Monograptus*. More recently Bouček (3*a*) has emended the genus *Linograptus* to make *Diversograptus posthumus* Richter the genoholotype and *Linograptus nilssoni* Frech a synonym. In his text-figure 18, under the name *Linograptus posthumus*, Bouček illustrates a specimen much like the Oklahoma form, except that his form has the simple tube-like thecae of *M. nilssoni* instead of flexed, retroverted thecae; and that the thecae are spaced 9 to 8 in 10 mm., as compared to 11 to 10 in 10 mm. in the Oklahoma form. Apparently nothing like this Oklahoma form has been found elsewhere, except in the German and Bohemian localities.

MONOGRAPTUS (LINOGRAPTUS) PHILLIPSI Decker var. MULTIRAMOSUS Decker, n. var.

Figures 42, 43

Syntypes.—Mus. Inv. Paleont. Univ. Oklahoma A2464, A2465.

Synrhabdosome with branches radiating from a central point, as in *M. phillipsi*, but differing from the latter in having about three times as many branches. Few are in position, however, to show the thecae. The thecae seen exhibit the characters of *M. phillipsi*. Only one specimen of this more complex colony was found, the two figures showing the original and counterpart of a single colony on two slabs of rock. If more specimens of this form are discovered, it may be found to deserve rank as a new species.

Occurrence.—Locality 1.

Genus CYRTOGRAPTUS Carruthers, 1867

CYRTOGRAPTUS SPARSUS Decker, n. sp.

Figures 15–17

Syntypes.—Mus. Inv. Paleont. Univ. Oklahoma A2466–A2468.

Cyrtograptus is represented by three fragments about 2.5 cm. long, two of which branch in the manner typical of the genus. The slender branches and the form of the thecae are much like those of the much older form *C. grayi*, but the Henryhouse form has only 6 to 8 thecae in 10 mm., while *C. grayi* has 9 in 10 mm. The width, 0.7 mm., corresponds closely in the two forms. However, the marked difference in age, and particularly the much sparser arrangement of the thecae, warrants the erection of the new species.

Occurrence.—Locality 1.

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SILURIAN PHYLLOCARID CRUSTACEANS FROM OKLAHOMA

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ABSTRACT

Three species of *Caryocaris* are described from the Henryhouse shale of Oklahoma, where they, as usual, are associated with graptolites.

The phyllocarid genus *Caryocaris* Salter has been recognized only in association with graptolites. It is, however, widly dispersed in geographic distribution, and possesses a long time range—from Early Ordovician into the Silurian. A single Silurian species, *C. siluricus* Ruedemenn (1), has been known hitherto, from Prince of Wales Island, Alaska. The present paper records three more, from the Henryhouse shale of Oklahoma, where these forms are associated with the graptolites described by Professor Decker on pages 434-446.

DESCRIPTION OF SPECIES

PHYLLOCARIDA Packard

Genus CARYOCARIS Salter

CARYOCARIS MAGNUS Ruedemann, n. sp.

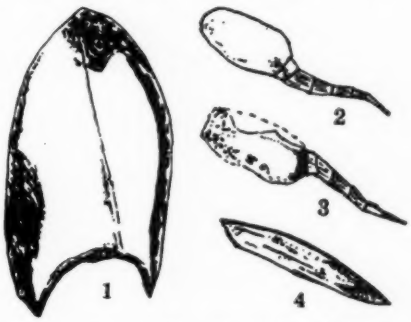
Figure 1

Holotype.—Mus. Inv. Paleont. Univ. Oklahoma A2469.

Carapace large; length 22 mm., width 12.5 mm.; elongate pod-shaped, each valve about 3½ times as long as high; anterior end forming a blunt angle; posterior end truncate, with concave emargination about 3 mm. deep and blunt lateral spines; ventral margin evenly convex, bending more abruptly towards the anterior extremity; no fringe of posterior spines has been observed, and no abdomen.

Locality: Henryhouse formation, Falls Creek, sec. 33, T. 1 S., R. 2 E., Murray County, Oklahoma; Chas. E. Decker, coll., 1934.

The single carapace, showing both valves from the underside, is somewhat



FIGS. 1—*Caryocaris magnus* Ruedemann, n. sp., holotype, ×2, Henryhouse shale, Falls Creek, Murray County, Oklahoma.
2, 3—*Caryocaris oklahomensis* Ruedemann, n. sp., holotype and counterpart, ×4, Henryhouse shale, Cool Creek, Carter County, Oklahoma.
4—*Caryocaris* sp., crushed specimen, ×4, same horizon and locality as last.

obliquely compressed, as seen from the oblique direction of the median hingeline. The outline is but little distorted, however, and indicates a robust carapace that may be distinguished from the associated *C. oklahomensis* by its much larger size, and from other species, save *C. curvilatus* Gurley (1*a*), by its less elongate form.

CARYOCARIS OKLAHOMENSIS

Ruedemann, n. sp.

Figures 2, 3

Holotype.—Mus. Inv. Paleont. Univ. Oklahoma A2470*a*, A2470*b*.

Carapace elongate, bean-shaped, twice as long as wide (length about 4 mm., height 1.9 mm.); anterior end probably obtusely rounded, posterior end truncated; dorsal margin slightly curved to straight, rather abruptly turned down in posterior fourth of length to the truncate posterior end; ventral margin slightly convex. Abdomen long (4.2 mm.); abdominal segments, five of which are seen, slender, forming a gradually tapering abdomen, ending in a narrow telson-spine. Lateral stylets not seen. Abdominal segments marked by distinct longitudinal striae or wrinkles.

Locality: Henryhouse shale, 8 feet above base, Cool Creek, sec. 36, T. 2 S., R. 2 E., Carter County, Oklahoma; Chas. E. Decker, coll., 1934.

C. oklahomensis differs from *C. siluricus* Ruedemann in its larger size and more elongate carapace, in lacking the pointed anterior end, and in its more slender abdomen.

CARYOCARIS sp.

Figure 4

Figured specimen.—Mus. Inv. Paleont. Univ. Oklahoma A2471.

The presence of a third species of *Caryocaris* in the Henryhouse shale is indicated by a third carapace of intermediate size and more slender form (partly due to oblique compression). The single specimen is, however, too incomplete for description.

Locality: Same as for last species.

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PALEONTOLOGICAL NOTES

AMERICAN INDIAN DISCOVERIES OF VERTEBRATE FOSSILS

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A collection of vertebrate fossils appeals to different types of men in very unlike ways. The thoughtful visitor sees in such an assemblage as may be found in various Natural History Museums in North America an epitome of the history and development of vertebrate animals on this planet; but the guard who makes the rounds of a big museum by night, making sure that "all is well" with the ghostly forms of other ages disclosed by his flash light, may see in a great Hall of Paleontology only a "bone shed." He has neither the vision of the philosophical mind, nor the mystical viewpoint of the Indian who encounters the skull or leg bone of some great vertebrate of past ages projecting from the bank of a stream.

The Tusayan Indians of Arizona formerly regarded an ammonite with veneration; it was a fetich "looked upon with reverence by the knowing ones and pronounced bad by the uninitiated." (3) On the Great Plains of Alberta the Blackfoot Indians secure the assistance of another cephalopod fossil in their hunting. A section of *Baculites* displaying the mysterious looking suture lines and often brilliant iridescence is set up in front of the tepee. By noting the direction in which it falls the owner learns the direction in which the best hunting lies (10).

The Indian is a keener observer of nature than the white man who found him still living in a world of magic and miracles. However when he finds a fragment of one of the large extinct animals he is likely to see in it not a clue to a chapter of the earth's history, but "big medicine" useful in offsetting the designs of the evil spirits from the Land of Shades.

An early discovery of vertebrate fossil remains in western Canada, one of the earliest records known to the writer, had just this significance to the Indian discoverer. Henry Youle Hind has, in the narrative of his exploration made in 1858 in the region of the large Manitoba lakes and eastern Saskatchewan, given the following account of an evening spent on the shore of Dauphin Lake with an old Ojibway Indian, who, half a century before the discovery of the dinosaur beds of the Red Deer valley, was acquainted with the location of a large vertebrate fossil in the bank of a river entering Dauphin Lake, Manitoba. At an Indian encampment at the west end of this lake, Hind writes,

> We found Ta-wa-pit, an old Ojibway with his two sons and their wives and children. Ta-wa-pit stayed during the greater part of the night by our camp-fire talking with the half-breed, smoking and drinking tea. He pointed out the spot near to us, where he was accustomed to take salt from the edges of a spring during the summer months. He described also at length the appearance and virtues of some gigantic bones exposed in the bank of Valley River near where it cuts through the old Lake Ridge. Ta-wa-pit calls these bones a great medicine, and, contrary to the usual custom of the Indians, he now and then takes small fragments, bruises them to powder, and uses them as a medicinal preparation. From his description I infer that the bones are those of a mammoth; his rough drawing of the ribs and teeth in the sand corresponded, in point of dimensions, with those of that gigantic animal (4).

These mammoth or mastodon remains that Hind reported 75 years ago to be used as medicine bag accessories of an Ojibway conjurer in exorcising evil Manitous, still await relocation and excavation. The relatively early date of this Indian discovery is apparent when we recall that J. B. Tyrrell's discovery of the first dinosaur skull in the Red Deer

valley, Alberta, was made in 1884, and recorded in the Government reports in 1885. E. D. Cope's announcement (1) of the discovery of vertebrate fossils by McConnell and Weston in the Cypress Hills region was also made in 1885. Prof. O. C. Marsh made his first trip to the Rocky Mountain states for fossils in 1868, ten years after Hind's interview with Ta-wa-pit. The chief interest in Hind's record lies in the fact that it antedates by many years any discovery known to the writer of vertebrate fossils by white men in Manitoba. This hoary record certainly deserves verification and exploitation by some vertebrate palaeontologist.

Another Indian discovery reported by J. B. Tyrrell (12) antedates by a few years Hind's record. Bones of a mastodon were brought to Fort Pelly previous to 1853, Tyrrell states, by the Indians who found them. They were discovered at the bottom of a landslide on the Shell, a branch of the Assiniboine. The superstitious Indians burned, so far as possible, the bones which were not taken to the Fort, and buried those which would not burn. The bones, which were received by J. W. Christie, eventually reached the British Museum, were described by Sir John Richardson (8) under the name of *Elephas ruperianus*, and were later identified as *Mastodon giganteus*.

Alongside Hind's record of the early discovery of vertebrate fossils in Manitoba may be cited Big Bone Lick in Kentucky—another discovery of the Redman. The story of the first collection made from this famous American locality for Pleistocene vertebrate fossils has been told elsewhere (5), but slight reference was made in the telling of it to the Indian or Indians who first found the teeth and tusks of the mastodon or mammoth at this noted locality. The colonial Indian-trader, John Croghan, who collected the first specimens from the "Great Bone Lick" to be studied by the savants of the time, found leading to it from the Ohio River a buffalo trail "spacious enough for two wagons to go abreast." Because of the salt and good hunting available there it is certain that the Indians had been acquainted with the locality for generations. In his letter transmitting a consignment of the first fossils from Big Bone Lick sent out of the Ohio Valley, Croghan definitely credits the Indians for directing him to the Big Bone lick. This highly interesting letter (15), addressed to Lord Shelbourne, then Secretary of State for the Southern Department in charge of the American Colonies, follows:

Right Honorable
My Lord:

I am just returned from my tour to the Illinois Country by the way of New Orleans, and have made a Report to his Excellency General Gage, of the Observations I made, respecting the Kings Service and of the Treaty I there held, with the numerous Body of Indians living in that Country. As the General, will no doubt transmit it, to your Lordship by this Packet I shall not presume to trouble you with it. In my passage down the River Ohio, I went to the Place, where the Indians had told me, There were some extraordinary Bones. I immediately discovered They were those of Elephants, and as They were the first ever met with, in any part of North America, the oldest Indians, have not the least traditional Trace of Them, I beg leave to acquaint your Lordship, That by the first Ship from hence to London, I shall do myself the Honor, of sending your Lordship, a Box containing some Tusks, Grinders, etc.

I have the Honor of being—
Right Honorable
My Lord
Your Lordships
most Obedient
and most faithful Servant
GEORGE CROGHAN

New York,
January 16, 1767.
The right Honorable The Earl of Shelburn.

The Indian guides who took George Croghan to the Kentucky salt lick that later yielded many thousands of pounds of bones of great American elephants and other representatives of a recently extinct fauna, contributed in an important way to the early development of paleontology in America. No other early discovery of fossils on this continent aroused so much interest in the vanished faunas of the past. Benjamin Silliman, of Yale University, after seeing a collection of these bones that included twenty-two tusks, wrote (9):

They produce in the beholder the strongest conviction that races of animals formerly existed on this continent, not only of vast magnitude but which must also have been

very numerous, and the Mastodon, at least, ranged in herds, over probably the entire American continents.

Thomas Jefferson, third president of the United States, was deeply interested in this discovery, and caused to be made at his own expense a collection of the Big Bone Lick fossils that filled a room of the White House. The only known skull of *Bootherium* was included in this collection.

It is most probable that the keen eye of the Indian has discovered various fossil localities other than those credited to him by Hind in Manitoba and Croghan in Kentucky. Living by the chase, with plenty as the reward for great skill in the hunt and starvation the penalty for lack of it, kept keeness of sight in fine trim; but extinct animals played no part in the game with starvation, and it is likely that only the medicine men gave heed to the great and mysterious bones that were sometimes met with. The trained eye of the professional collector readily catches traces of fossils that escape the notice of the untrained eye of either the Indian or the white-man. Charles H. Sternberg (11), the veteran collector, has figured a well-exposed dinosaur skeleton directly on a trail traversed for years by Indians and "cow-boys," who apparently never saw this well-exposed specimen.

While "bone-hunting" did not appeal to the Indian, fossil bones were at certain localities in the Rocky Mountain states so abundant that the Indian could hardly have failed to discover them before the arrival of the white-man. One of these amazing localities is the noted Bone Cabin Quarry, on the Medicine Bow River in southern Wyoming. At this place a Mexican sheep herder had built the foundations of his cabin of the gigantic limb bones and other parts of dinosaurs. Indians of the region must have been familiar with these bones long before the cabin was discovered by Walter Granger (6) in 1898, when he began with Wortman the excavation of the now famous Bone Cabin quarry.

The earliest fossils from the High Plains of the western United States reached Joseph Leidy via St. Louis fur-traders, who had penetrated as far west as the badlands of the Cheyenne River (7). It is very probable that some of the examples of this strange new fauna, which Leidy described in 1847–1855, were found by Indians.

The Indians of the Black Hills disliked the expeditions which Prof. O. C. Marsh led into their territory in the seventies and at times were distinctly hostile toward the white "bone-hunters" who invaded the hunting grounds of their ancestors. They probably felt, however, that when "among wolves one must howl a little," and they sometimes made minor contributions to Marsh's collections. It is related that Professor Marsh's name, *Brontotherium*, or "thunder beast," was suggested by a Black Hills Indian who brought in his tobacco pouch a tooth, which, he said, had belonged to "big horse struck by lightning."

The instructions given to David Thompson (13) by the officers of the North West Company in 1797, when he set out on his long surveying and exploring expedition, assigned him four principal duties:

(1) To determine the 49th parallel.
(2) To visit the Mandan Indians.
(3) To search for fossil bones of large animals.
(4) To determine the positions of the trading posts of North West Company.

Thompson's manuscript journals, Mr. Tyrrell informs me, contain no evidence that he ever found any fossil bones of large animals or that he ever looked for them (14). The request of his employers to "search for fossil bones of large animals," however, strongly suggested that some of the Company's officials had heard from the Indians of the existence of such bones in the west. They probably had in mind the possibility of developing in Canada a profitable trade in fossil ivory, such as had been carried on with the natives of Siberia for centuries.

All collectors of fossils have been considered by many of the illiterate with whom they come in contact, "queer," if not worse. That Prince of Collectors, Charles Darwin (2), who collected everything from insects to dinosaur bones, tells a good story about himself related to him by a German naturalist named Renous. This gentleman, whose mastery of Spanish caused him to be mistaken for a native, asked a Chilean lawyer, who had met

Darwin, what he thought of this Englishman, who went about breaking rocks with a hammer and putting bugs, minerals and animals of all sorts in his collecting bag. After deep thought he replied:

> It is not well—hay un gato encerrado aqui (there is a cat shut up here). No man is so rich as to send out people to pick up such rubbish. I do not like it; if one of us were to go and do such things in England do you not think the King of England would very soon send us out of his country?

Renous himself had previously learned what the Chileans in San Fernando thought of an entomologist. Some years before he had left there, under charge of a girl, caterpillars to feed, that they might turn into butterflies. Rumors of this spreading through the town led the padres and the governor to consult together and agree that it must be some heresy. Renous, when he returned, was accordingly arrested.

It is still true, as it was in Darwin's day, that a large share of the populace is suspicious of those individuals who have as their main objective in life "the increase and diffusion of knowledge among men." It was no doubt vastly more true in the Indian social organization, and the Indian who neglected his hunting and scalp-lifting to search for fossil remains of the animals of the Happy Hunting grounds of other days, would have been in even worse repute among his fellow braves than Renous was in San Fernando. Having in mind this viewpoint of the workings of the primitive type of mind the rather short list of fossil discoveries that can be credited to the Indian is not surprising. This record, however, includes at least two discoveries of considerable importance. The early description of some of the Big Bone Lick fossils of Kentucky, which resulted from the Indians' acquaintance with them previous to the coming of the white man, stands near the beginning of paleontology in North America. We are also indebted to the Indian for finding and collecting, in spite of his superstitious fear of them, the first fossil bones from the Great Plains of Canada that received scientific study and description.

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15. The writer is indebted to Dr. J. F. Kenney, Director of Historical Research and Publicity, Public Archives of Canada, for notice of this letter.

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NEOTYPES IN ZOOLOGICAL NOMENCLATURE

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The term *neotype* was proposed by Cossmann (1) in two senses: First, as a genotype by subsequent designation or elimination; and second, as a specimen from the type locality of a species, chosen as type of that species in the event of loss or destruction of the original types. The second use of the term was adopted by Schuchert (2), and is in general use among paleontologists today. The term was recommended by Banks and Caudell (3), but is not recognized in the *International Rules of Zoological Nomenclature*. Howell (4) proposed the term *neoholotype* to apply to a specimen of the neotype series corresponding to the holotype of the original type material. Plummer and Howell (5) proposed the term *neoparatype* which is to bear the same relationship to neoholotype as paratype bears to holotype. Both are special kinds of neotypes.

In a case in which the original types of a species *A* are lost or otherwise unavailable, and in which two or more species (all fitting the description of species *A*) occur at the type locality, can the identity of species *A* be established by the designation of a neotype? If the designation of a neotype is not to be accepted, how is the identity of species *A* to be determined? The following case has been submitted to the International Commission on Zoological Nomenclature in the hope of obtaining a ruling on the validity of the term neotype. We are interested primarily in the principle involved, and not merely in the solution of the problem offered by the following example.

Example.—In 1858, Shumard (6) described *Fusulina elongata* as follows:

> Shell nearly cylindrical, very slender and much elongated, pointed at the extremities, which are slightly curved; chambers very numerous; aperture very narrow, linear, extending the entire length. Surface covered with fine, somewhat flexuous striae.
>
> *Dimensions.*—Length, from one to two inches; width, from one to two lines. This species is at once distinguished from *F. cylindrica* by its remarkable length.
>
> Occurs in the White Limestone [Capitan formation], Dark Limestone and Sandstone [Delaware Mountain formation] of the Guadalupe Mountains of New Mexico and Texas.

No illustration accompanied Shumard's original description, and his types, unfortunately, have been lost.

According to J. W. Skinner (7), there are at least seven species, belonging to two genera, at the type locality of "*F.*" *elongata* Shumard, all answering to the original description. Skinner also stated that Girty (8), in his figures and description of "*F.*" *elongata* Shumard, based on specimens from the type locality, included at least four species belonging to two genera.

Dunbar and Skinner (9) rejected the name "*F.*" *elongata* Shumard, reasoning that:

> Since several species and at least two genera occur within the stratigraphic limits indicated, all of which fall within the extremes of the dimensions given, there is no possibility of deciding which was actually described by Shumard.

These authors proposed the genera *Parafusulina* and *Polydiexodina*, with the new species *Parafusulina wordensis*, *Polydiexodina capitanensis* and *Polydiexodina shumardi*. The latter two species were described from the type locality of "*F.*" *elongata;* and the text strongly suggests that the first, *P. wordensis*, may also occur there.

Discussion.—It is obvious that, if the law of priority is to hold, the name "*Fusulina*" *elongata* Shumard must be applied to some species occurring in the Capitan or Delaware Mountain formations of the Guadalupe Mountains. It is most desirable that all workers apply the name to the same species. Since the original types of this species have not been preserved, there seems only one way of tying the name to a definite species,

namely, by the selection of a neotype. An alternative solution of the problem might be to declare the name "*F.*" *elongata* a *nomen dubium*.

There are important objections, however, to regarding "*F.*" *elongata* as a *nomen dubium*. The description was adequate when made, and distinguished *elongata* from other described species. Further, an adequate type locality was added. Rejection of a name merely because several species fit the description would establish a dangerous precedent. No author of a species can describe against the future, especially since there is an increasing tendency toward finer differentiation of species. To allow a reviser to reject a specific name as "unrecognizable," and to rename the biological units upon which that name obviously was based, would certainly not tend toward a stabilization of nomenclature.

Article 25 of the *Rules of Zoological Nomenclature* states plainly that:

> The valid name of a genus or species can be only that name under which it was first designated on the condition: (*a*) That this name was published and accompanied by an indication, or a definition, or a description; and (*b*) That the author has applied the principles of binary nomenclature.

Thus it is indisputable that "*Fusulina*" *elongata* Shumard must be a valid name for some species.

Dunbar and Skinner make the point that: " . . . there is no possibility of deciding which [of the several species] was actually described by Shumard." However, since all of the several species occurring at the type locality fit the original description of "*F.*" *elongata*, and since they all occur within the stratigraphic limits indicated for that species, we can infer only that they were all included in Shumard's species, and that the species, in effect, has been divided by a subsequent reviser. In this regard, article 24 of the Rules states:

> When a species is divided, the restricted species to which the original name of the primitive species is attributed may receive a notation indicating both the name of the original author and the name of the reviser.

This implies, at least, the procedure that should be followed in the case of "*F.*" *elongata*.

If the holotype of a composite species such as "*F.*" *elongata* were in existence, there would be no doubt that it would represent the species to which the original name must be attributed. When the original types are completely unavailable, however, the reviser must select arbitrarily the species to bear the name. If, at the same time, he can designate a neotype which will be sanctioned by the Rules as they now authorize a holotype, such procedure will certainly tend to stabilize nomenclature, and prevent some of the permutations of names, which are so common at present.

(It is expected that the specific case cited in this article will come before the International Commission on Zoological Nomenclature in September. Paleontologists who may wish to express an opinion in the matter may address the Secretary of the Commission, Dr. C. W. Stiles, at the Smithsonian Institution, Washington, D. C.—Editor.)

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DIATOMS FROM QUATERNARY LAKE BEDS NEAR CLOVIS, NEW MEXICO

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During the summer of 1933, Mr. Edgar B. Howard, of the University of Pennsylvania, made extensive archeological excavations near Clovis, New Mexico, and brought to light many artifacts, together with some vertebrate fossils. During the course of the excavations a series of samples of sand and clay were collected, of which 18 were submitted to the writer on the chance that they might contain diatoms. The results of the examination of these samples are presented here.

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THE SAMPLES AND THEIR FOSSIL CONTENT

Of the 18 samples examined, 13 were found, by the usual cleaning and concentration, to contain diatoms. Some of the samples were suites representing the top, middle, and bottom zones of an exposure, whereas others were isolated samples representing only one stratigraphic level. The localities that yielded diatoms are as follows:

1. Pit, east side, top of blue sand. South half of sec. 25, T. 1 N., R. 35 E., Roosevelt County, New Mexico. U.S.G.S. diatom locality 1772.
2. Pit, east side, middle of blue sand, same locality. U.S.G.S. diatom locality 1773.
3. Pit, east side, bottom of blue sand, same locality. U.S.G.S. diatom locality 1774.
4. Pit, west side, top of blue sand, same locality. U.S.G.S. diatom locality 1775.
5. Pit, west side, middle of blue sand, same locality. U.S.G.S. diatom locality 1776.
6. Pit, west side, bottom of blue sand, same locality. U.S.G.S. diatom locality 1777.
7. Anderson Lake, no. 2, Erosion Island, top of blue sand. East half of sec. 10, T. 1 S., R. 35 E., and west half of sec. 7, T. 1 N., R. 34 E. U.S.G.S. diatom locality 1778.
8. Anderson Lake, no. 2, Erosion Island, middle of blue sand, same locality. U.S.G.S. diatom locality 1779.
9. Anderson Lake, no. 2, Erosion Island, bottom of blue sand, same locality. U.S.G.S. diatom locality 1780.
10. Anderson Lake, no. 2, north side, blue sand, same locality. U.S.G.S. diatom locality 1781.
11. Anderson Lake, no. 2, west side, blue sand, same locality. U.S.G.S. diatom locality 1782.
12. Anderson Lake, no. 2, south side, blue sand, same locality. U.S.G.S. diatom locality 1783.
13. Anderson Lake, no. 2, northeast side, top of blue sand, same locality. U.S.G.S. diatom locality 1784.

The list of species in Table 1 shows both the distribution and relative abundance of the diatoms found. In all of the samples, the diatoms constituted only a minor part of the total quantity of material, most of which was clay, sand, or both. Hence, considerable cleaning and concentration of the diatoms present was necessary, but since each sample received the same degree of concentration, the abundances indicated may be considered as truly relative.

Out of the total of 88 species, 67 are living at present in fresh-water lakes and streams; and 21 are living sparingly in fresh-water lakes, but more frequently in saline lakes and brackish estuaries. The latter are indicated on the list by an asterisk after the name.

All of the species recorded are still living in approximately the same latitude in other parts of the world, though their geologic ranges are not fully known, and an accurate age determination is, therefore, not possible. In view of the fact that all of the species are still living a late age is suggested, possibly late Pleistocene or early Recent. Many of the specimens were broken, suggesting the possibility of reworking of an older deposit, although the relatively coarse matrix in which these diatoms were deposited may indicate conditions that would account for the break-

TABLE 1.—DIATOMS FROM QUATERNARY LAKE BEDS NEAR CLOVIS, NEW MEXICO

Sample number	1	2	3	4	5	6	7	8	9	10	11	12
Melosira granulata (Ehrenberg) Ralfs	—	—	—	—	R	—	—	—	—	—	—	—
Melosira islandica O. Müller	—	—	—	—	R	—	—	—	—	—	—	—
Melosira italica (Ehrenberg) Kützing	—	—	—	—	F	—	—	R	—	—	—	R
Melosira varians Agardh	—	—	—	—	R	—	—	—	—	—	—	—
Cyclotella meneghiniana Kützing	—	—	—	—	—	—	—	—	—	R	—	F
Meridion circulare (Greville) Agardh	—	—	—	—	F	F	—	—	—	—	—	F
Fragilaria brevistriata Grunow	—	—	—	—	—	F	—	F	—	—	—	—
Fragilaria construens (Ehrenberg) Grunow	—	—	—	—	F	R	—	—	—	—	—	—
Fragilaria pinnata Ehrenberg	—	—	—	—	—	F	—	—	—	—	F	—
Synedra ulna (Nitzsch) Ehrenberg	—	—	—	—	C	C	C	—	—	—	R	C
Synedra ulna spathulifera Grunow	—	—	—	—	—	—	—	—	—	—	—	F
Eunotia valida Hustedt	—	—	—	—	R	R	—	—	—	—	—	—
Eunotia gracilis (Ehrenberg) Rabenhorst	—	—	—	—	R	—	—	—	—	—	—	—
Eunotia monodon Ehrenberg	—	—	—	—	—	—	—	—	R	—	—	—
Eunotia pectinalis (Kützing) Rabenhorst	—	—	—	—	R	—	—	—	—	—	—	—
Cocconeis placentula Ehrenberg*	—	—	—	—	C	F	R	—	—	F	F	—
Cocconeis thumensis Mayer	—	—	—	—	—	F	—	—	—	—	—	—
Achnanthes lanceolata (Brébisson) Grunow	—	—	—	—	F	—	—	—	—	—	—	—
Rhoicosphenia curvata (Kützing) Grunow*	—	—	—	—	R	—	—	—	—	—	—	—
Mastogloia elliptica (Agardh) Cleve*	R	—	—	—	—	—	C	—	—	—	F	—
Mastogloia grevillei W. Smith	—	—	—	—	—	R	—	—	—	—	—	—
Mastogloia smithii lacustris Grunow	—	—	—	—	—	—	—	—	—	—	—	C
Gyrosigma attenuatum (Kützing) Cleve	—	—	—	—	—	F	—	—	—	—	—	—
Neidium iridis (Ehrenberg) Pfitzer	—	—	—	—	F	F	F	R	—	—	—	R
Diploneis elliptica (Kützing) Cleve*	—	—	—	—	F	—	—	—	—	—	—	—
Diploneis ovalis (Hilse) Cleve*	C	R	—	—	R	F	R	—	—	—	F	—
Diploneis ovalis oblongella (Naegeli) Cleve*	R	—	—	—	—	—	R	—	—	—	—	—
Stauroneis acuta W. Smith	—	—	—	—	R	—	—	—	—	—	—	—
Stauroneis anceps Ehrenberg	—	—	—	—	F	F	—	—	—	—	—	—
Stauroneis phoenicenteron (Nitzsch) Ehrenberg	—	—	—	—	R	R	—	—	—	—	—	—
Anomoeoneis sphaerophora (Kützing) Pfitzer*	F	—	—	—	R	F	F	—	—	—	F	F
Navicula ambigua Ehrenberg	—	—	—	—	—	—	—	—	—	—	—	R
Navicula cuspidata Kützing	—	—	—	—	R	—	—	—	—	R	—	—
Navicula dicephala (Ehrenberg) W Smith	—	—	—	—	R	—	—	—	—	—	—	—
Navicula exigua (Gregory) O. Müller	—	—	—	—	R	—	—	—	—	—	—	—
Navicula gastrum Donkin	—	—	—	—	F	—	—	—	—	—	—	—
Navicula longirostris Hustedt*	—	—	—	—	R	—	—	—	—	—	—	—
Navicula oblonga Kützing	—	—	—	—	F	—	—	—	—	R	—	—
Navicula pupula Kützing	—	—	—	—	F	—	—	—	—	—	—	—
Pinnularia borealis Ehrenberg	F	—	—	—	—	—	—	—	—	R	—	—
Pinnularia dactylus Ehrenberg	—	—	—	—	—	F	R	—	—	—	—	—
Pinularia divergentissima (Grunow) Cleve	—	—	—	—	—	R	—	—	—	—	—	—
Pinnularia gibba Ehrenberg	—	—	—	—	F	—	—	—	—	—	—	—
Pinnularia cf. *P. lata* (Brébisson) W. Smith	—	—	—	—	—	R	—	—	—	—	—	—
Pinnularia leptosoma (Grunow) Cleve	R	—	—	—	—	—	—	—	—	—	—	—
Pinnularia molaris (Grunow) Cleve	C	—	—	F	—	—	—	—	—	—	R	—
Pinnularia nobilis Ehrenberg	—	—	—	—	F	—	—	—	—	—	—	—
Pinnularia viridis (Nitzsch) Ehrenberg	—	—	—	—	F	—	—	—	—	—	R	F
Pinnularia viridis fallax Cleve	—	—	—	—	F	—	—	—	—	—	—	—

TABLE 1.—DIATOMS FROM QUATERNARY LAKE BEDS NEAR CLOVIS, NEW MEXICO (*Continued*)

Sample number	1	2	3	4	5	6	7	8	9	10	11	12
Amphora ovalis Kützing	—	—	—	—	R	—	R	—	—	—	—	F
Cymbella affinis Kützing	—	—	—	—	C	—	F	—	—	R	F	C
Cymbella aspera (Ehrenberg) Héribaud.	—	—	—	—	—	C	—	R	—	—	—	—
Cymbella ehrenbergii Kützing	—	—	—	—	—	F	—	—	—	—	R	—
Cymbella cf. *lanceolata* (Ehrenberg) Kirchner	F	—	—	—	—	—	—	—	—	—	—	—
Cymbella cf. *C. naviculiformis* Auerswald.	—	—	—	—	—	F	—	—	—	—	—	—
Cymbella parva (W. Smith) Van Heurck.	—	R	—	—	—	C	—	—	—	—	—	—
Cymbella prostrata (Berkeley) Cleve	—	—	—	—	—	—	—	—	—	—	—	F
Cymbella ventricosa Kützing	—	—	—	—	—	F	F	—	—	—	—	—
Gomphonema acuminatum coronatum (Ehrenberg) W. Smith	—	—	—	—	F	R	—	—	—	—	—	—
Gomphonema constrictum Ehrenberg	—	—	—	—	C	—	—	—	—	—	—	—
Gomphonema intricatum Kützing	—	—	—	—	—	F	—	—	—	—	—	C
Gomphonema intricatum pumillium Grunow	—	—	—	—	—	F	—	—	—	—	—	—
Gomphonema lanceolatum insignum (Gregory) Cleve	—	—	—	—	F	—	F	—	—	—	R	C
Gomphonema cf. *semiapertum* Grunow	—	—	—	—	—	—	—	R	—	—	—	—
Gomphonema cf. *olivaceum* (Lyngbye) Kützing*	—	—	—	—	—	—	—	R	—	—	—	—
Denticula elegans Kützing	F	—	—	—	—	—	—	—	—	—	—	—
Denticula cf. *D. thermalis* Kützing	F	—	—	—	—	—	—	—	—	—	—	—
Denticula valida Pedicino	F	R	R	C	—	C	F	F	—	—	F	R
Epithemia argus (Ehrenberg) Kützing*	—	—	—	—	—	—	—	—	—	—	C	—
Epithemia argus alpestris (W. Smith) Grunow*	—	—	—	—	—	—	—	R	—	—	—	—
Epithemia muelleri Fricke	A	R	—	C	—	C	—	—	—	—	R	—
Epithemia sorex Kützing	—	—	—	—	—	—	R	—	—	—	—	—
Epithemia turgida (Ehrenberg) Kützing*	—	—	—	R	C	C	—	F	—	R	—	—
Epithemia zebra porcellus (Kützing) Grunow*	—	—	—	—	—	F	R	—	—	—	R	—
Epithemia zebra saxonica (Kützing) Grunow*	C	—	—	—	—	—	—	R	—	—	—	—
Rhopalodia gibba (Kützing) O. Müller*	F	R	R	C	—	F	F	—	—	—	F	F
Rhopalodia gibberula (Ehrenberg) O. Müller*	F	—	—	F	—	—	—	R	—	—	R	F
Nitzschia amphibia Grunow	R	—	—	R	F	—	—	—	—	—	R	R
Nitzschia denticula Grunow	—	—	—	—	C	F	F	—	—	—	F	C
Nitzschia palea (Kützing) W. Smith	—	—	—	—	R	—	—	—	—	—	—	—
Nitzschia hungarica Grunow*	—	—	—	—	—	—	—	—	—	—	—	R
Cymatopleura cf. *C. elliptica* (Brébisson) W. Smith*	—	—	—	—	F	F	—	—	—	—	R	—
Surirella cf. *S. ovalis* Brébisson*	—	—	—	—	F	—	—	—	—	—	—	R
Surirella robusta splendida (Ehrenberg) Van Heurck	—	—	—	—	R	—	—	—	—	—	—	—
Surirella spiralis Kützing	C	—	—	—	—	C	—	—	—	—	—	—
Surirella cf. *S. turgida* W. Smith	—	—	—	—	R	—	—	—	—	—	—	—
Campylodiscus clypeus bicostata (W. Smith) Hustedt	—	—	—	—	—	—	—	—	—	—	F	—
Campylodiscus cf. *C. noricus* Ehrenberg	—	—	—	—	—	C	—	R	—	—	—	—

Relative abundance: A = abundant; C = common; F = few; R = rare.

Note: Only one species, *Denticula valida* Pedicino, was found in sample no. 13, and, as it occurred rarely, no column was inserted in the table for this sample.

age without implying such reworking. If the material has been re-worked, no reasonable correlations between the various beds would be possible, but since the re-working of the beds cannot be proven and at best is only suggested, an attempt at correlation seems justified.

CORRELATION

By means of a census of the species in each sample and a consideration of their relative abundance, the tentative correlation shown in Table 2 was evolved. This correlation is based on the most abundant species in each bed and may indicate the true relationships if, as mentioned above, the possibility of reworking is eliminated. An examination of the species list in Table 1 will indicate a rather spotty distribution of some of the species. In no case is there close duplication of species in beds which have been considered equivalent in the tentative correlation offered, but, instead, a fairly close duplication of the most abundant species. In many cases there are species listed in one bed and not in its proposed correlative. The most probable explanation for this is that in all of the samples studied, the diatoms were present only as a minor constituent of the total bulk of the sediment. Therefore, although fairly large samples were concentrated, the individual assemblages may not be truly representative. This holds true, of course, principally for those species listed as rare and, to a less degree, for those listed as frequent.

As a further check on these correlations, and also to provide some idea of the environment prevailing at the time of deposition, a study of the type of ecology represented by the various assemblages was undertaken. The percentage of species living in both fresh water and saline (non-marine) waters was determined for each sample and indicated on Table 2. In computing these percentages, the different species have been weighted according to their abundance. The results obtained are most striking in the case of samples nos. 1 to 6, taken on two sides of a large pit. An increase in salinity is shown going up in the section in each case, indicating, most probably, an increase in aridity of the region with consequent evaporation and concentration of the water in the lake.

TABLE 2.—*Tentative chronologic correlation of diatom-bearing samples*

Pit		Anderson Lake			
East Side	West Side	Erosion Island	North Side	West Side	South Side
1 35%	4 35%	—	—	—	—
2 25%	5 25%	7 29%	10 25%	11? 57%	12 17%
3 25%	6 15%	8 53%	—	—	—
—	—	9	—	—	—

Note: The upper figure of each vertical pair is the sample number; the lower figure is the percentage of species of saline-water habitat.

In the case of Anderson Lake, the picture is not so clear. Sample Nos. 7, 10, 11, and 12 seem to fit most closely into the same horizon as 2 and 5 on the basis of species content. The ecologic data, however, are somewhat anomalous. Nos. 7 and 10 fit quite well into the previous picture, but No. 11 represents the most highly saline assemblage of the whole region and No. 12, its correlative on a species basis, is nearly the least saline. In the "Pit" series of samples there is a definite indication of an increase in salinity going up in the section, whereas the situation is just reversed in the case of "Erosion Island" in Anderson Lake.

Only one whole diatom and one fragment was found in sample No. 9, the lowest col-

lected, so nothing of value could be obtained. Sample no. 8, immediately overlying No. 9, contained 13 species which, after weighting according to abundance, indicated 53 percent were species inhabiting saline waters today. Sample no. 7, immediately overlying No. 8, contained 17 species of which only 29 percent were saline types. It would therefore appear from this evidence that Anderson Lake was decreasing in salinity at the same time that the lake which covered the present "Pit" was increasing in salinity. It is quite possible that this decrease was only temporary and that an examination of beds overlying the ones studied would indicate an increase in salinity. Samples were not available from these higher beds, however, so this must remain pure speculation for the present.

The high salinity indicated by the diatom assemblage in sample No. 11 is somewhat anomalous. This sample contains the highest percentage of saline types in any of the samples and the correlation is questioned on this ground, although equivalence of species would place the bed as in the table. On the basis of relative salinity, it should be placed equivalent to sample No. 8. On the other hand, if the salinity again increased, it should be correlated with higher beds. Since, however, it fits best as shown in the table on a species basis, it is left there but with a doubt indicated. Although re-working of a fossil assemblage is all too frequently considered where anomalies appear, it is quite possible that the present one is due to this cause. This possibility is further strengthened by the fact that most of the species are broken and a perfect individual is only rarely found and then only among the smaller forms.

Although the salinity indicated by sample No. 12 is lower than that in other beds correlated with it, the difference is not great, and the correlation indicated is probably as sound as any in the table.

SUMMARY

Eighteen samples of sand and clay were cleaned and examined for diatoms with the following results:

1. 88 species and varieties of diatoms were found in 13 of the samples. Eleven samples contained assemblages sufficient for comparison.

2. All of the species found are still living in approximately the same latitude, indicating a probable late Quaternary age for all of the beds.

3. The high degree of breakage of the diatoms in all of the samples suggests that the materials may have been re-worked, but the evidence is not at all conclusive.

4. On the assumption that re-working has not taken place, a tentative correlation between the various beds is proposed.

5. A study of the ecologic factors involved supports the tentative correlation with but two exceptions. In one basin progressive increase in salinity going up in the section is indicated, while in the second basin there is a suggestion of decreasing salinity going up in the section. An anomalous situation is introduced in the second basin by an assemblage which fails to fit into the general scheme. The possibility of re-working is suggested to explain this anomaly.

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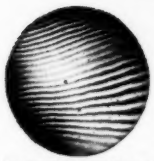

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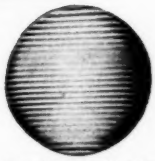

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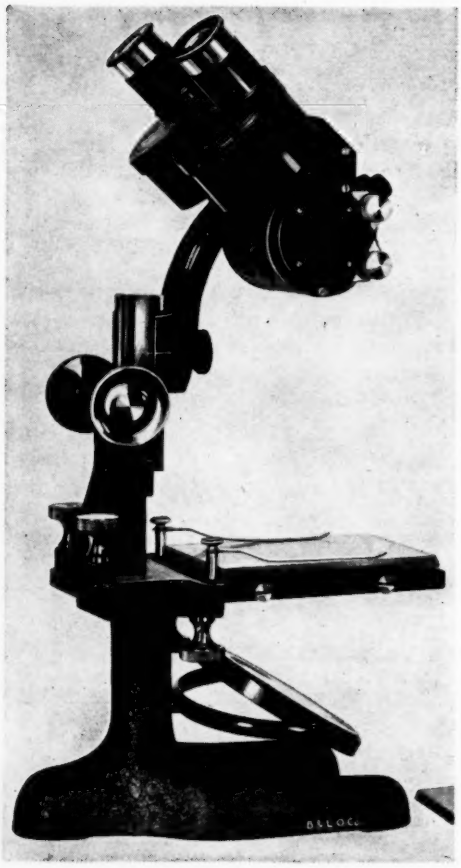

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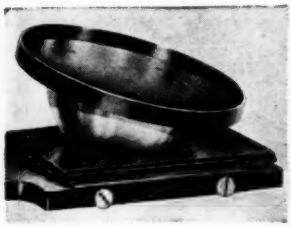

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